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SECTION: 1 of 8

DOCUMENT #: DOE/RL-92-67, DRAFT C

TITLE: Draft RI/FS Report for 1100-EM-1 OU, Hanford

START

1 of 3

DOE/RL-92-67
DRAFT C

Draft Remedial Investigation/ Feasibility Study for the 1100-EM-1 Operable Unit, Hanford

Date Published
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ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ACM	Asbestos containing materials
amsl	Above Mean Sea Level
ANF	Advanced Nuclear Fuels
ANSI	American National Standards Institute
API	American Petroleum Institute
APR	Air purifying respirator
ARAR	Applicable or relevant and appropriate requirements
ARAR's	Legally applicable, or relevant and appropriate, Federal and State environmental standards
ASR	Air supplying respirator
ASTM	American Society for Testing and Materials
AWP	Asbestos work permit
BDAT	Best demonstrated available technology
BEHP	Bis (2-ethylhexyl) phthalate
β-HCH	Beta-Hexachlorocyclohexane
BISRA	Baseline Industrial Scenario Risk Assessment
BRSRA	Baseline Residential Scenario Risk Assessment
BWTF	Buried Waste Test Facility
CAA	Clean Air Act
CAS	Chemical Abstracts Service
CBC	Complete blood count
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
CFR	Code of Federal Regulations
CFWQC	Chronic freshwater quality criterion
CGI	Combustible gas indicator
CLP	Contract Laboratory Procedure
cm^3	Cubic centimeter
cms	Cubic meters per second
CNS	Central nervous system
CO_2	Carbon dioxide
COC	Contaminants of concern
COPC	Contaminants of potential concern
CPC	Chemical protective clothing
CPR	Cardiopulmonary resuscitation
CRC	Contamination reduction corridor
CRQL	Contract Required Quanitfaction Limit
CRZ	Contamination reduction zone
CWA	Clean Water Act
dBA	Decibels on A-weighted scale
DDT	1,1,1-trichloro-2, 2-bis(p-chlorophenyl)ethane
DHHS	U.S. Department of Health and Human Services
DNR	Washington State Department of Natural Resources
DOE	U.S. Department of Energy

ACRONYMS
(Continued)

DOE-RL	U.S. Department of Energy Field Office, Richland
DOI	U.S. Department of the Interior
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
DOW	Washington State Department of Wildlife
Ecology	Washington State Department of Ecology
EIS	Environmental impact statement
EM	Equipment maintenance
EMI	Electromagnetic inductance
EP	Ephemeral Pool
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
ESLI	End-of-service-life indicator
FD&CA	Food, Drug, and Cosmetic Act
FEF	Forced expiratory flow
FID	Flame ionization detector
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRC	Functional residual capacity
FS	Feasibility Study
ft	Foot
g	Gram
gal	Gallons
GC	Gas chromatography
G/kg	Grams per kilogram
g-mole	Gram-mole
GM	Groundwater monitoring
GMU	Game management unit
gpm	Gallons per minute
GPR	Ground-penetrating radar
HEHF	Hanford Environmental Health Foundation
HEIS	Hanford Environmental Information System
Hg	Mercury
HM	Hazardous material
HMS	Hanford Meteorological Station
HNF	Hanford Nuclear Facility
HNU	A photoionization detector manufactured by the HNU Co.
HOC	Halogenated organic compound
HQ	Hazard quotient
hr	Hour
HRL	Horn Rapids Landfill
HRS	Hazard ranking system
HSBRAM	Hanford Site baseline risk assessment methodology
HSDB	Hazardous substances data base
HSP	Health and Safety Plan

ACRONYMS
(Continued)

HSPA	Hanford Site Performance Assessment
HSO	Health & Safety Officer
HSPA	Hanford Site performance assessment
HWP	Hazardous work permit
HWO&ER	Hazardous waste operations and emergency response
HWOP	Hazardous waste operating permit
HWQHC	Human water quality health criterion
HWQWC	Human water quality welfare criterion
ICR	Incremental cancer risk
IDL	Instrument detection limit
IDLH	Immediately dangerous to life and health
in	Inches
IP	Ionization potential
IR	Infrared
IRIS	Integrated Risk Information System
IU	Isolated unit
JSA	Job Safety Analysis
kg	Kilograms
K_h	Horizontal conductivity
km	Kilometers
K_v	Vertical conductivity
L	Liter
lb	Pound
LC	Lethal concentration
LD	Lethal dose
LDLO	Lethal dose low
LDR	Land disposal restriction
LD50	Medium lethal dose
LEL	Lower explosive limit
LFL	Lower flammable limit
LOAEL	Lowest observed adverse effect level
LOEL	Lowest observed effect level
m	Meter
m^3	Cubic meter
MAG	Magnetometer
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MD	Metal detector
MEFR	Maximal expiratory flow rate
Metals	Mercury, cadmium, chronium, etc.
μg	microgram
mg	Milligram
mg/kg	Milligram per kilogram
ML	Milliner

ACRONYMS
(Continued)

MMHG	Milliner of mercury
mrem	Milliroentgen equivalent in man
MS	Mass Spectroscopy
MSDS	Material safety data sheet
MSHA	Mine Safety and Health Administration
MSWLF	Municipal and Solid Waste Landfill
MTCA	Model Toxics Control Act
MVV	Maximal voluntary ventilation
MW	Monitoring well
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	No observed adverse effect level
NOEL	No observed effect level
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NTP	National Toxicology Program
O_2	Oxygen
O&M	Operation and Maintenance
ORM	Other regulated materials
OSHA	U.S. Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	Operable unit
OVA	Organic vapor analyzer
OVM	Organic vapor meter
PAH	Polycyclic aromatic hydrocarbons
PAPR	Powered air-purifying respirator
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene (perchlorethene)
PCP	Pentachlorophenol
PDS	Personnel decontamination station
PEL	Permissible exposure limit
PEST.	Pesticides
pH	Hydrogen ion concentration
PID	Photoionization detector
PMF	Probable maximum flood
PNL	Pacific Northwest Laboratory
POC	Point of compliance
ppb	Parts per billion
ppbv	Parts per billion by volume
PPE	Personal protective equipment
ppm	Parts per million

ACRONYMS
(Continued)

PRC	PRC Consultants
PRG	Preliminary remediation goal
psi	Pounds per square inch
PSPL	Puget Sound Power and Light
PTL	Project team leader
PVC	Polyvinyl chloride
QAPjP	Quality Assurance Project Plan
QAPP	Quality Assurance Program Plan
QTRC	Quality Training and Resource Center
RAD	A unit for the measurement of radioactivity
RAM	Radioactive material
RAO	Remedial action objective
RBC	Red blood count
RCRA	Resource Conservation and Recovery Act
REL	Recommended exposure limit
REM	A measurement of radiation dose meaning roentgen equivalent man.
RfD	Reference dose
RHO	Rockwell Hanford Operations
RI	Remedial Investigation
RME	Reasonable maximum exposure
RV	Residual volume
RWP	Radiation Work Plan
SAR	Supplied-air respirator
SARA	Superfund Amendments and Reauthorization Act
SC	Specific conductance
SCBA	Self-contained breathing apparatus
SCS	U.S. Soil Conservation Service
SDG	Sample delivery group
SDWA	Safe Drinking Water Act
SF	Slope factor
SOP	Standard Operating Procedure
SpG	Specific gravity
SPC	Siemens Power Corporation
SQL	Sample quantitation limit
STEL	Short-term exposure limit
SVOC	Semivolatile organic compound
S_y	Storage coefficient
ta	Ambient air temperature
ta adj	Adjusted ambient air temperature
TAL	Target analyte list
TBC	To be considered
Tc-99	Technetium-99
TCA	1,1,1-trichloroethane
TCE	Trichloroethene

ACRONYMS
(Continued)

TCL	Target compound list
TCLo	Lowest observed toxic concentration
TDLo	Lowest observed toxic dose
TDS	Total dissolved solids
TIC	Tentatively-identified compounds
TLC	Total lung capacity
TLV	Threshold Limit Value
TLV-C	Threshold limit value - ceiling
TLV-STEL	Threshold limit value - short-term exposure limit
TOC	Total organic carbon
TORR	A unit of pressure equal to 1 mm Hg
TOX	Total organic halogen
TP	Test Pit
TPA	Tri-Party Agreement
TSCA	Toxic Substance Control Act
TSD	Treatment, storage, or disposal facility
TWA	Time-weight average
UCL	Upper confidence limit
UEL	Upper explosive limit
UFL	Upper flammable limit
UN	Unplanned and unauthorized release
USC	United States Code
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USF&WS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTL	Upper tolerance limit
UV	Ultraviolet
VOC	Volatile organic compound
WAC	Washington Administrative Code
WDOE	Washington State Department of Ecology
WHC	Westinghouse Hanford Company
WIDS	Waste Information Data System
WOE	Weight-of-evidence
WPPSS	Washington Public Power Supply System
WSGMA	Washington State Growth Management Act
WSU	Washington State University
XRF	X-ray fluorescence

EXECUTIVE SUMMARY

This Remedial Investigation/Feasibility Study (RI/FS) presents the results of field and analytical investigations conducted at the 1100-EM-1 Operable Unit at the U.S. Department of Energy (DOE) Hanford Reservation located near the city of Richland in Benton County, Washington (Volumes I-III). Also, the results of a Limited Field Investigation/Focussed Feasibility Study (LFI/FFS) are presented for the 1100-EM-2, 1100-EM-3, and 1100-IU-1 Operable Units (Volume IV). In addition, this report develops and evaluates a range of remedial technologies to address potential threats to human health and the environment.

This document conforms with current guidance for the conduct and preparation of RI and FS of hazardous waste sites pursuant to the National Oil and Hazard Substance Pollution Contingency Plan (NCP) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Also, National Environmental Policy Act (NEPA) values were integrated into the procedural and documentation requirements of the CERCLA process. Table ES-1 provides a directory identifying the location of specific NEPA values in the 1100-EM-1 documents.

Based on the referenced descriptions, there are no cultural resource areas such as archaeologic and/or historic sites; no endangered or threatened species and their critical habitats; nor environmentally important natural resource areas such as floodplains, wetlands, important farmlands, and/or aquifer recharge zones in the areas affected by any potential remedial actions. However, nothing in this or other documents prepared for the investigation, characterization, and assessment of the site are intended to present a statement on the legal applicability of NEPA actions under CERCLA.

This report fulfills DOE's agreed obligation milestone M-15-01B/C as mandated by the Hanford Federal Facility Agreement and Consent Order, commonly referred to as the Tri-Party Agreement.

The 1100-EM-1 Operable Unit is one of four operable units within the 1100 Area. The 1100 Area was placed on the National Priorities List in July 1989. Recent efforts on the part of DOE, the Environmental Protection Agency (EPA), and others to accelerate the characterization and remediation of the entire 1100 Area led to an expedited investigation of the 1100-EM-2, 1100-EM-3, and 1100-IU-1 Operable Units as well. The results of this investigation are now available and are incorporated into this report as an addendum entitled Draft LFI/FFS for the 1100-EM-2, 1100-EM-3, and 1100-IU-1 Operable Units (Volume IV). The Record of Decision developed from this RI/FS report and addendum will then address the entire 1100 Area.

The bulk of this RI/FS report, however, focuses on individual subunit or waste disposal areas within the 1100-EM-1 Operable Unit. The three most significant subunits are the Discolored Soil Site, the Ephemeral Pool, and the Horn Rapids Landfill (HRL). Investigation and analysis of contamination, especially groundwater at HRL, has involved coordination with Siemens Power Corporation, who is independently investigating contaminated groundwater beneath its facility. The scope and scheduling of data collection

Table ES-1. NEPA VALUE LOCATION DIRECTORY

NEPA VALUE	1100-EM-1 DOCUMENT	1100-EM-1 DOCUMENT
	DOE/RL-90-18	DOE/RL-92-67
PHYSICAL CHARACTERISTICS		
Operable Unit Vicinity	Section 3.1	Section 1.4
Meteorology	Section 3.2	Section 2.1
Hydrology	Section 3.3	Section 2.3
Geology	Section 3.4	Section 2.2
ECOLOGICAL CHARACTERISTICS		
Human Ecology	Section 3.7.1	
Land Use	Section 3.7.1.1	
Water Use	Section 3.7.1.2	
Cultural Resources	Section 3.7.1.3	
Wildlife Ecology	Section 3.7.2	Appendix L
Terrestrial Ecology	Section 3.7.2.1	
Aquatic Ecology	Section 3.7.2.2	
Sensitive Environments	Section 3.7.2.3	
IMPACTS OF REMEDIAL ACTIONS		
Compliance with Statutory Law		Section 9.1.2, Appendix M
Short-Term Impacts		Section 9.1.5
Long-Term Impacts		Section 9.1.3
Impacts to Resources		Section 9.1.6, Appendixes G & N
Effects to Public Health		Sections 5.1, 5.2, 7.2, 9.2, Appendix K
AGENCIES/PERSONS CONTACTED		Section 1.2
LAND USE, POLICIES, CONTROLS		Section 7.1, Appendix J

activities for the entire RI has been subject to substantial negotiations based on concerns for and potential impacts to groundwater and the nearby North Richland well field.

This RI/FS report summarizes and evaluates the followup analysis of both the intrusive and nonintrusive activities at the several subunits. The majority of the soil analyses and geophysical surveys were completed in early phases of this investigatory effort. Important new activities completed in the later phases of the RI include the collection of six additional rounds of groundwater samples, and excavation of several exploratory trenches at HRL. Analytical results of these efforts are presented in the appendixes.

Three main areas of concern were identified. These are: 1) approximately 340 cubic meters of contaminated soil at the Discolored Soil Site [bis (2-ethylhexyl) phthalate (BEHP) concentration up to 25,000 parts per million (ppm)]; 2) approximately 250 cubic meters of polychlorinated biphenyls (PCB's) contaminated soil at the Ephemeral Pool (PCB $<$ 42 ppm); and 3) approximately 460 cubic meters of PCB contaminated soils (PCB $\leq$ 100 ppm), the presence of friable asbestos in surface soils, and overlapping groundwater plumes at HRL. The trichloroethene (TCE) (up to 110 ppm) plume is approximately 1.6 kilometers (km) (1 mile) long by 0.3 km (0.2 miles) wide. The nitrate (up to 63 ppm) plume is approximately 2.0 kilometers (km) (1.3 miles) long by 0.8 km (0.5 miles) wide. Contaminants noted at these areas exceed Federal and/or state environmental regulatory criteria, including the Safe Drinking Water Act (SDWA) and the State of Washington's Model Toxics Control Act (MTCA).

Potential risk to human health and the environment were assessed. Incremental cancer risks were evaluated for both industrial and residential scenarios. For industrial use, the risks were determined to be in the range of 2E-5 to 5E-5. For residential use the risks were determined to be in the range of 2E-3 to 3E-3. The 95 percent upper confidence level concentrations for contaminants were used to evaluate and develop the risk ranges.

Identification and analysis of mobility and migration of contaminants was evaluated through the use of both unsaturated and saturated zone flow and transport models. Results from the modelling and analysis activities suggest groundwater contaminants will migrate but attenuate to levels at or below regulatory concern within 12 to 22 years.

A wide range of treatment options were reviewed. These options were screened for technical and practical applicability, and evaluated for effectiveness. Viable and practicable process technologies were then assembled into groups of alternatives to provide for remediation of those contaminants exceeding criteria. Incorporated into the alternatives for the soil contaminants, were processes or technologies including, bioremediation, supercritical CO_2 extraction, excavation with offsite disposal, and incineration. For the groundwater contamination, processes involving extraction, treatment, and infiltration were considered as was an approach relying upon natural attenuation. Additional consideration was given to costs. An estimate was developed for each alternative.

Finally, each of the alternatives that survived the review, screening, and evaluation, including a no action alternative, were considered against evaluation criteria pursuant to the NCP and CERCLA. These evaluations were completed to provide objective comparison of remedial alternatives for the 1100-EM-1 Operable Unit to allow for risk management decisions by the appropriate regulatory agencies.

A separate executive summary is presented for the LFI/FFS results in Volume IV.

1.0 INTRODUCTION

The 1100 Area of the U.S. Department of Energy's (DOE) Hanford Reservation was placed on the National Priorities List (NPL) in July 1989, pursuant to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, 42 U.S.C. 9601 *et seq*. Based on both documented and undocumented past practices at the 1100 Area, it was determined that pollutants were released to the environment and that those contaminants might present a danger to the public health, welfare, and the environment.

In anticipation of regulatory actions, the U.S. Department of Energy Field Office, Richland (DOE-RL) divided the 1100 Area into four operable units and initiated CERCLA response planning. DOE-RL, the U. S. Environmental Protection Agency (EPA), and the Washington Department of Ecology (Ecology) jointly assigned the 1100-EM-1 Operable Unit the highest priority, within both the 1100 Area and the Hanford Site as a whole. This priority was assigned based on reported past practices at the site and the proximity of residential areas of the city of Richland and the North Richland well field.

The Hanford Federal Facility Agreement and Consent Order, also referred to as the Tri-Party Agreement (TPA) issued in May 1989, governs all CERCLA efforts at Hanford. The Remedial Investigation (RI)/Feasibility Study (FS) work plan (DOE/RL-88-23), mandated by the TPA, led to the first phase of the RI, which was completed in the summer of 1990. The Phase I RI report (DOE/RL-90-18) was issued in August 1990, followed by the Phase I and II FS Report (DOE/RL-90-32) issued in December 1990.

The Phase II RI was initiated with the publication of the draft RI Phase II Supplemental Work Plan (DOE/RL-90-37) in October 1990.

According to the TPA, the Phase II RI was due for completion in September 1991. Due to changes in the scope of remedial characterization activities, DOE, EPA, and Ecology renegotiated the Phase II RI milestone, M-15-01B, and combined it with the Phase III FS milestone M-15-01C, to become the combined RI Phase II/Phase III FS milestone M-15-01B/C with the new submittal date of December 1992. This RI/FS for the 1100-EM-1 Operable Unit, Hanford has been prepared to meet the DOE's obligations for that combined milestone.

1.1 PURPOSE OF REPORT

The Phase I RI report concentrated on the initial site characterization for the 1100-EM-1 Operable Unit. This report focuses on more complete site characterization as well as an additional investigation of problematic issues developed during Phase I. These issues included development of more detailed analysis of groundwater contamination, risk assessment and land use at and near the operable unit proper. A description of the activities undertaken is found in the Phase II RI Supplemental Work Plan (Revision II) DOE/RL-90-37. It is noteworthy that some tasks originally planned in early versions of the RI Phase II Work Plan have been deleted while other tasks have been modified or added.

Discussions detailing these changes are found in the introduction to the RI Phase II Supplemental Work Plan (Revision II). This report complements the initial characterization, providing a more definitive characterization of the nature and extent of the contaminants and threats to human health and the environment posed by contaminant releases from the operable unit.

This document also presents the Phase III FS results. Included are the review and analysis of appropriate remedial technologies and evaluation of several remedial options for the restoration of the 1100-EM-1 Operable Unit in accordance with pertinent regulatory criteria.

This document is intended to be a self-contained report. It is important to note, however, that to avoid unnecessary duplication, this document will refer frequently to previously published reports on the 1100 Area, especially the Phase I RI and the Phase I/II FS Reports noted above. It is the intent to provide only sufficient redevelopment of older material to allow the reader to follow the logic of the technical discussions presented in this report. Familiarity with previous investigative reports published on the 1100 Area, especially as presented in DOE/RL-90-18 and DOE/RL-90-32, is assumed for a critical review of the findings and recommendations presented in this document. As noted, this document reports primarily on those activities outlined in the Phase II RI Supplemental Work Plan, Revision II.

The TPA identifies a RI Phase II Report as a primary document. As such, regulatory agencies have the opportunity to comment, and the DOE the opportunity to respond to those comments within a certain time period. Revisions and/or modifications to this RI/FS will follow guidelines as stated in paragraph 9.2.1 of the TPA.

1.2 NATIONAL ENVIRONMENTAL POLICY ACT

This report has also been prepared to provide an environmental analysis consistent with the Council on Environmental Quality regulations for implementing the procedural requirements of the National Environmental Policy Act (NEPA) and the DOE regulations and orders for implementing NEPA. This analysis is to consider the need for a proposed remedial measure, alternatives considered, and the environmental impacts associated with each alternative.

The regulatory authority for the proposed action is discussed above in section 1. Table ES-1 provides a directory identifying the location of specific NEPA values in the 1100-EM-1 Operable Unit documents. The affected environment is described in detail in sections 2, 3, and 4. The environmental and human health impacts and the rationale for requisite actions at the site are presented in sections 5 and 6. In sections 7, 8, and 9, remedial alternatives are developed, screened, and assessed. Effectiveness, implementability, and other criteria are also evaluated to determine if protection of human health and the environment are being addressed, and to meet the intent of regulatory criteria.

To date, numerous agencies and persons have been contacted including: EPA Region 10, Hanford Project Office; Ecology, Hanford Facility Project Office; Siemens Power Corporation (SPC); the Department of the Interior (DOI); and the National Oceanic and Atmospheric Administration (NOAA). Additional agencies and persons will be contacted through the public and regulatory review process for this document.

1.3 NATURAL RESOURCE TRUSTEES

CERCLA and the Clean Water Act (CWA), 33 U.S.C. 1251-1376, provide that natural resource trustees may assess damages to natural resources resulting from a discharge of oil or a release of a hazardous substance covered under CERCLA or the CWA and may seek to recover those damages. To this end, a Preliminary Natural Resource Survey was completed by NOAA. Within this survey, specific references to the 1100-EM-1 Operable Unit are not made. Moreover, the relative size of the 1100 Area is small compared to the entire Hanford site; hence, only limited references are made to the 1100 Area in this survey.

According to the NCP [section 300.160 (a)(3)] the lead agency shall make available to the trustees of affected natural resources information and documentation that can assist the trustees in the determination of actual or potential natural resource injuries. This RI/FS with its Ecological Assessment and analysis of alternatives is to be used by DOE in lieu of a Preassessment Screen for Natural Resource Damages Assessment (43 CFR 11).

The trustees for natural resources are NOAA, DOE, and the State of Washington. Potential trustees include the following Indian Tribes: Confederated Tribes and Bands of the Yakima Indian Nation, the Nez Perce Indian Tribe , the Confederated Tribes of the Umatilla Indian Reservation, and the Confederated Tribes of Warm Springs Reservation. Copies of this report are to be made available to the trustees and potential trustees for Natural Resources.

1.4 REPORT ORGANIZATION

This RI/FS for the 1100-EM-1 Operable Unit is organized in a format comparable to that recommended by EPA (1988). This document does, however, combine the RI/FS portions under a single cover. The intent is to minimize the repetition of background materials without sacrificing the technical detail necessary to make an informed decision for appropriate remediation of the site. This subsection assists the reader in understanding the presentation format and in locating information of specific interest. This RI/FS consists of eight sections in addition to this introduction, the bibliography, and associated appendixes.

- Section 1: Provides a concise site description, general history, and background of the 1100-EM-1 Operable Unit.

- Section 2: Presents a summary of the physical characteristics of the 1100-EM-1 Operable Unit.

- Section 3: Summarizes the data collection activities performed as documented in the RI/FS work plans.

- Section 4: Discusses the nature and extent of contamination at the site.

- Section 5: Presents contaminants of concern along with summaries of human health baseline risk assessments for industrial and residential scenarios and ecological risk assessments posed by hazardous substances released from 1100-EM-1 Operable Unit.

- Section 6: Analyzes the environmental fate and transport of contaminants at the operable unit. Potential operable unit contaminant migration pathways are documented, contaminant characteristics relevant to migration are assessed, and transport modeling is performed to estimate current and future contaminant concentrations in each environmental medium.

- Section 7: Identifies remedial action objectives, general response actions, and screens and evaluates remedial technologies and process options.

- Section 8: Develops and screens remedial alternatives.

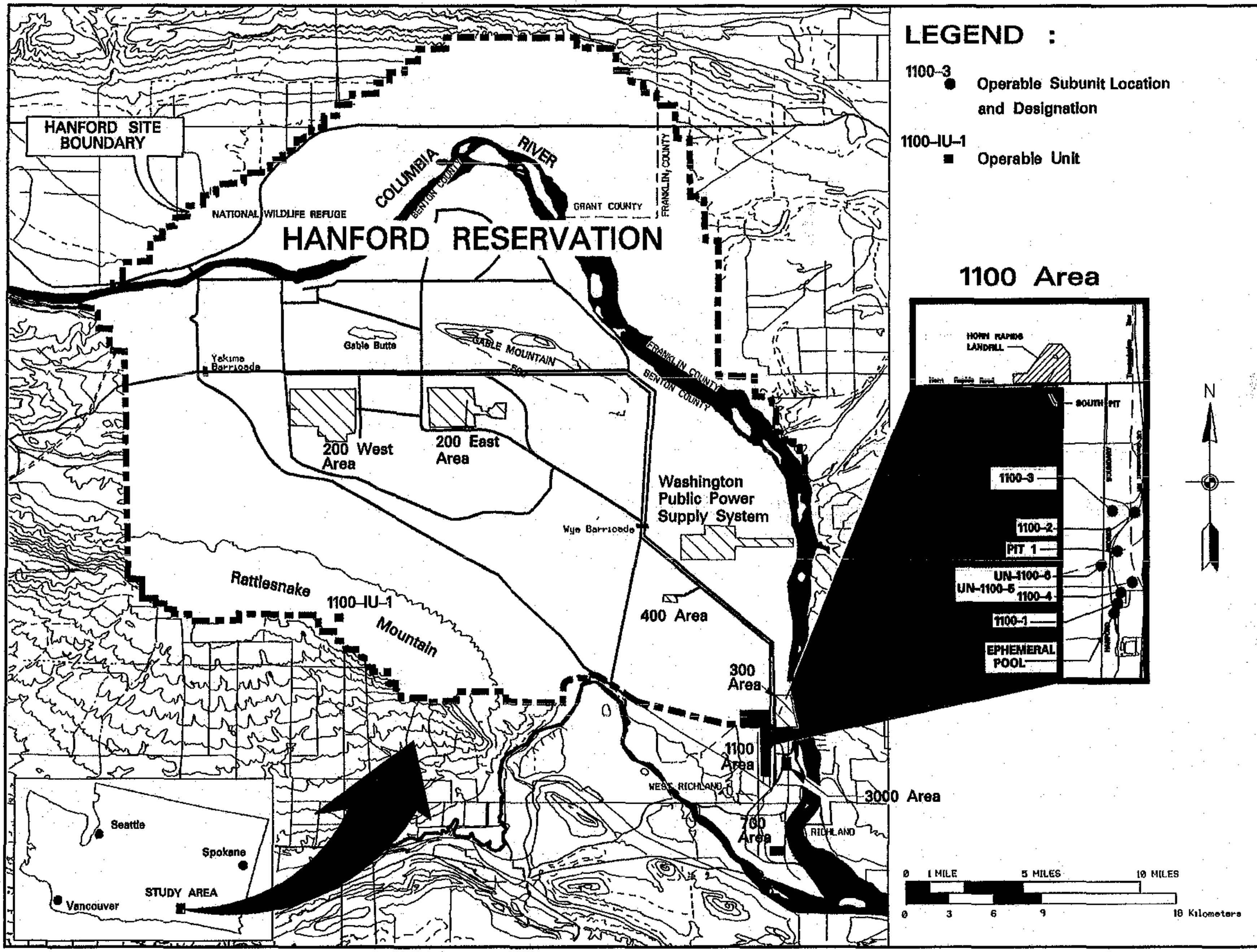
- Section 9: Provides comparison of the alternatives against regulatory evaluation criteria.

- Section 10: Presents references cited in the body of the text.

- Appendixes: Present letters, memoranda, technical data, concise summaries of validated analytical data, and details of technical analyses needed to confirm the findings contained within the text.

1.5 1100-EM-1 OPERABLE UNIT BACKGROUND

The 1100 Area is located in the southern-most portion of the Hanford Site, adjacent to the city of Richland in Benton County, Washington (see figure 1-1). As defined by EPA for purposes of site designation, the 1100 Area includes portions of the 600, 700, and 3000 Areas. The 600 Area nominally includes all land within the Hanford site not otherwise within the 100, 200, 300, 400, or 1100 Areas and consists mostly of undeveloped land and some relatively remote facilities. The 700 Area is primarily comprised of administrative buildings and is located outside of the Hanford Reservation proper in downtown Richland; it is centered around the Federal Building on Jadwin Avenue in Richland. The 3000 Area is located outside of, but adjacent to, the Hanford Site; it also is comprised mostly of administrative buildings, but includes some technical support and warehouse storage facilities as well.



Hanford Reservation Location Map

Fig. 1-1

The 1100 Area NPL Site is currently divided into four operable units. The 1100-EM-1, 1100-EM-2, and 1100-EM-3 Operable Units, are shown in figure 1-2. The 1100-IU-1 Operable Unit is located 24 kilometers (km) west of the 1100 Area proper near Rattlesnake Mountain (see figure 1-1).

Each operable unit is designated with a three-part code. The first part indicates the NPL site affiliation, in this case the 1100 Area NPL Site. The second part provides a shorthand description of the operable unit type: EM indicates "equipment maintenance;" IU indicates "isolated unit." The final portion of the code simply provides a unique numeric designator for each operable unit.

The 1100-EM-1 and 1100-EM-2 Operable Units are comprised of different sets of waste management units that are, for the most part, located within the 1100 Area proper.

The 1100-EM-3 Operable Unit contains the 3000 Area waste management units and is physically separated from the remainder of the 1100 Area by a major thoroughfare, Stevens Drive.

Within the 1100-EM-1 Operable Unit are numerous individual sites or waste disposal areas that are identified as subunits (see figure 1-2). These subunits have been designated with descriptive names (*e.g.*, The Discolored Soil Site) and/or a simple alphanumeric code (*e.g.*, UN-1100-6). This nomenclature will be followed in this report.

Recent efforts on the part of DOE, EPA, and others to expedite the remediation and eventual delisting of the entire 1100 Area led to an expedited investigation of the 1100-EM-2, 1100-EM-3, and the 1100-IU-1 Operable Units. This investigation is now complete with the results presented as an addendum [Draft Limited Field Investigation/ Focussed Feasibility Study (LFI/FFS) for the 1100-EM-2, 1100-EM-3, and 1100-IU-1 Operable Units, Volume IV] to this RI/FS.

The Record of Decision developed from this report and addendum is intended to address the entire 1100 Area, a considerable expansion of the original focus on the 1100-EM-1 Operable Unit. This accelerated schedule is intended to provide for more effective utilization of resources.

1.5.1 Nearby Properties and Facilities

The North Richland well field has been of particular interest during the course of the 1100-EM-1 investigation. Located 0.8 km east of the 1171 building in the 1100 Area, the well field is still used to supplement city of Richland water supplies (see figure 1-2). Columbia River water is pumped to the well field and allowed to percolate through the soil. This procedure reduces turbidity and improves water quality for industrial and residential usage. Initial concerns focussed on the potential impact of migration of contaminants from the 1100 Area to the well field. The findings of the RI indicate there is no reasonable scenario under which contaminants in groundwater in the 1100-EM-1 Operable Unit would impact the city well fields.

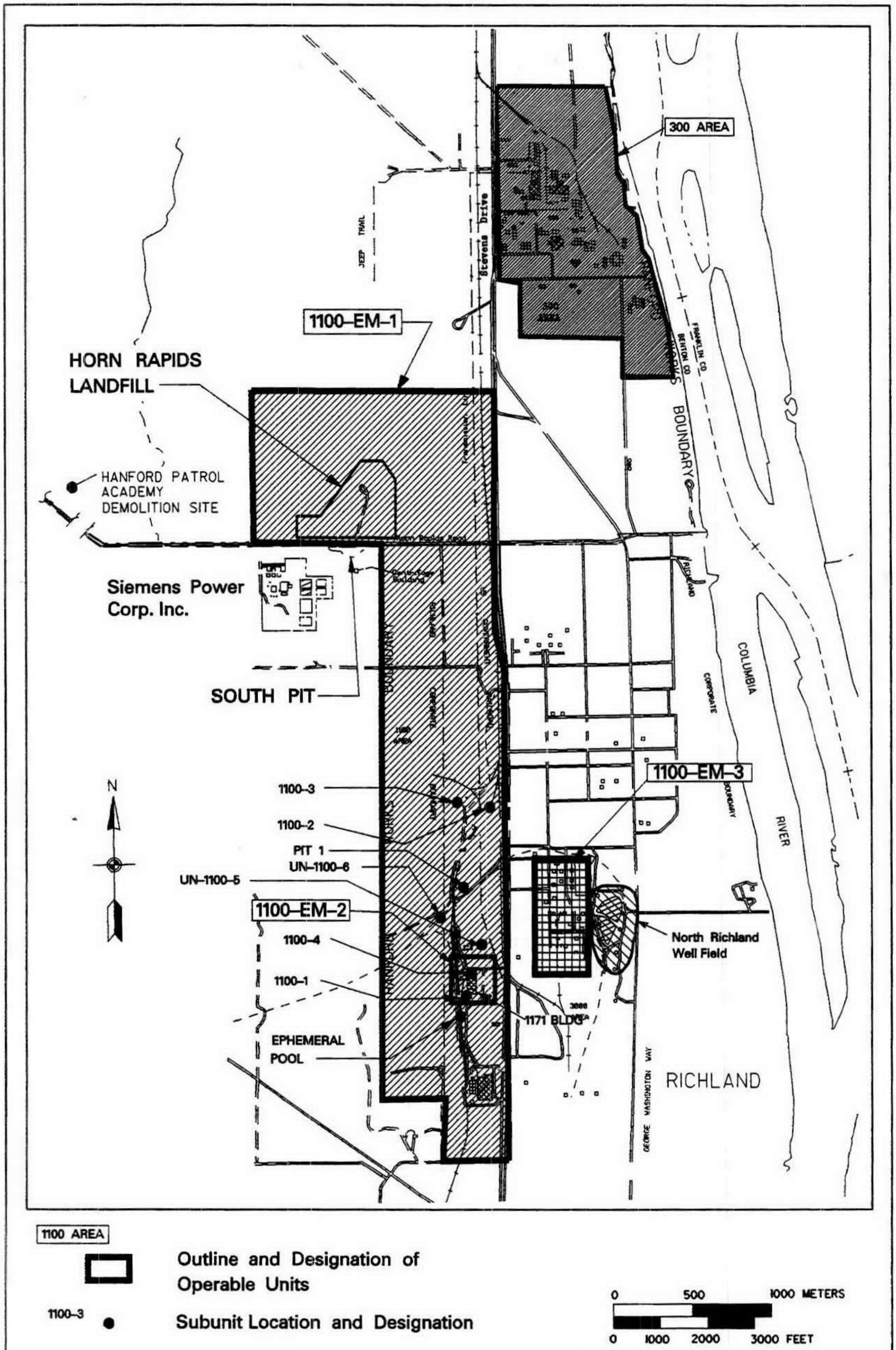


Figure 1-2. 1100 Area Operable Units

During the course of this RI for the 1100-EM-1 Operable Unit, agreements were made between DOE, EPA, Ecology, and others to investigate the groundwater at the Horn Rapids Landfill (HRL) and adjacent properties. Currently, SPC owns property which abuts the 1100 Area, specifically near the HRL. The owner and/or corporate entity charged with this property has undergone several name changes even during the course of this investigation. Previous designations include Exxon Nuclear Fuels, Advanced Nuclear Fuels, Siemens Nuclear Power and, as noted above, SPC.

The scope and scheduling of RI activities has been influenced by the participation of the SPC. Coordination with SPC on groundwater data collection and distribution has been ongoing since early 1990. In March 1991, DOE formally briefed SPC on the DOE 1100-EM-1 Operable Unit investigation. SPC's participation in the DOE investigation has continued since this meeting. However, SPC is pursuing their own investigation of groundwater underlying their facility and potential sources of contamination as a separate investigation from DOE's activities at the HRL and 1100-EM-1.

Both DOE and SPC will consider and evaluate data generated by the other party's investigation. Data, as received from SPC, is included in this document, where appropriate.

1.5.2 1100-EM-1 Operable Unit Description

The 1100 Area is the central warehousing, vehicle maintenance, and transportation distribution center for the entire Hanford site. A wide range of materials and potential waste products were routinely used at and near the 1100 Area. Table 1-1 lists potential waste products either presumed or known to have been used at the 1100-EM-1 Operable Unit. Known toxic or chemical constituents of these products are presented as well.

The 1100-EM-1 Operable Unit has been divided into several subunits based on the nature of previous use and potential contaminants. The subunits are:

- 1100-1 (The Battery Acid Pit): An unlined dry sump, or french drain, used for disposal of waste acid from vehicle batteries. Historical documents record an estimated 57,000 liters (L) [15,000 gallons (gal)] of battery acid wastes may have been disposed of between 1954 and 1977.

- 1100-2 (The Paint and Solvent Pit): A former sand and gravel pit subsequently used for the disposal of construction debris and reportedly, waste paints, thinners and solvents.

- 1100-3 (The Antifreeze and Degreaser Pit): A former sand and gravel pit used for the disposal of construction debris along with potential disposal of antifreeze and degreasing solutions.

- 1100-4 (The Antifreeze Tank Site): A former underground storage tank used for the disposal of waste vehicle antifreeze. This tank was emptied in 1986, cleaned, and removed due to suspected leakage.

Table 1-1. Toxic Constituents in 1100-EM-1 Operable Unit Potential Waste Products

Waste Product	Toxic Element
antifreeze	ethylene glycol, propylene glycol
automotive cleaners[1]	cresol, ethylene dichloride, sodium chromate, petroleum distillates, 1,1,1-trichloroethane
battery acid[2]	lead, sulfuric acid, arsenic, cadmium
contact cement[1]	toluene, hexane, methyl ethyl ketone, trichloroethane
degreasers	1,1,l-trichloroethane, trichloroethane
gasoline	C_3-C_{12} aliphatic hydrocarbons, xylene, benzene
hydraulic oils	PCB's
industrial lubricants[1]	trichloroethane, lead naphthenate
lacquer thinners[1]	ethyl acetate, butyl acetate, butyl alcohol, toluene, xylene, aliphatic hydrocarbons
metal cleaners[1]	potassium carbonate, trisodium phosphate, tetrachloroethane, trichloroethane, kerosene[b], chromic acid
paints, latex[3]	ethylene glycol, zinc
paints, oil-based[4]	linseed oil[c], mineral spirits[d], lead, zinc
paints, other[3,4]	toluene, methyl ethyl ketone, chromium, zinc, lead
paint removers	dichloromethane, methyl ethyl ketone
paint thinners	mineral spirits[d]
penetrating oils[1]	kerosene[b], xylene, carbon tetrachloride
roof patching sealants[1]	kerosene[b], gasoline, mineral spirits[d]
solvents	acetone, carbon tetrachloride, gum turpentine, methanol, 1,1,1-trichloroethane, stoddard solvent[e]
stains[1]	mineral spirits[d], aniline dyes
undercoating material[1]	aromatic hydrocarbons, aliphatic hydrocarbons, phenolic resins, methyl isobutyl ketone
vinyl adhesives[1]	benzene, toluene
waste oil[5]	C_{10}-C_{16} alkanes, toluene, 1,1,1-trichloroethane, polycyclic aromatic hydrocarbons (PAH's)

[a] Petroleum distillates are hydrocarbon fractions such as gasoline and kerosene.
[b] Kerosene contains aromatic hydrocarbons and C_5-C_6 aliphatic hydrocarbons.
[c] Linseed oil contains flaxseed oil and additives such as lead, manganese, and cobalt.
[d] Mineral spirits contains benzene, toluene, hexane, and cyclohexane.
[e] Stoddard solvent contains C9-C12 aliphatic hydrocarbons, naphthalene, and aromatic hydrocarbons.

[1] Gosselin et al. 1984.
[2] Eckroth 1981.
[3] Ash and Ash 1978.
[4] Myers and Long 1975.
[5] EPA 1974.

- UN-1100-5 (The Radiation Contamination Incident): On August 24, 1962, radioactive contamination was discovered on an incoming 1,452 kilograms (kg) (16-ton) shipment cask containing irradiated metal specimens from a facility at the Idaho National Engineering Laboratory. The truck trailer on which the contamination was detected, had offloaded other cargo at another building and was parked in the parking lot northwest of the 1171 Building when the contamination was detected.

- UN-1100-6 (The Discolored Soil Site): The location of an unplanned release onto the ground surface involving an unknown quantity of organic waste liquids.

- The HRL: A solid waste facility used primarily for the disposal of office and construction waste, asbestos, sewage sludge, fly ash, and reportedly, numerous drums of unidentified organic liquids. Classified documents were also incinerated at a burn cage located at the northern edge of the landfill.

- The Ephemeral Pool: An elongate, man-made depression into which parking area runoff water collects and evaporates leaving behind contaminant residues.

- Pit 1: An active gravel/borrow pit north of the 1171 building.

- The South Pit: A "disturbed" area on the south side of Horn Rapids Road, across from HRL. Scattered debris of unknown origin has been found on the ground surface.

- The Hanford Patrol Academy Demolition Site: An ash pit used for the disposal of unstable chemicals by detonation, is located approximately 2 kilometers (km) [1 mile (mi)] to the west of HRL. This demolition site is identified in WHC (1989a) as a potential Resource Conservation and Recovery Act (RCRA), 42 USC 6901 *et seq.*, treatment, storage, or disposal (TSD) waste management unit.

In all of these areas, a number of distinct surveys and/or investigations have been performed. Several of the older surveys and analytical results have been presented in previously published work plans and/or reports and are not repeated here. During the efforts associated with this final phase of the investigation, some of the work was focussed on the particular uses and past practices of a specific subunit, while other studies concentrated on operable unit wide containment issues. Before providing a review of the investigations, surveys and studies undertaken at the entire operable unit, a brief review of the physical characteristics of the 1100 Area is presented in section 2.

2.0 PHYSICAL CHARACTERISTICS OF THE 1100-EM-1 OPERABLE UNIT

This chapter provides a summary of important physical parameters and processes that have contributed to the conditions existing at each of the various 1100-EM-1 Operable Unit subunits. Previous reports provided detailed information on these subunits (DOE/RL-90-18). Only those salient items that provide immediate support to the Phase II RI presentation will be repeated in the development of the hypotheses and conclusions made in this document.

2.1 METEOROLOGY

Meteorological data is summarized in appendix D of DOE/RL-90-18. Data was obtained from historical records gathered at the Hanford Meteorological Station (HMS), the Hanford 300 Area automated meteorological station, and the Richland, Washington Airport.

The climate of the Hanford Site has been classified as mid-latitude semiarid or mid-latitude desert, depending on the classification scheme employed. Summers are warm and dry with abundant sunshine. Winters are cool with occasional precipitation (Hulstrom, 1992). Average high air temperatures at the HMS reach 37°C (100°F) during the summer, and drop to lows of -5°C (23°F) in winter. Historical extremes are recorded as 46°C (115°F) and -29°C (-20°F). Annual highs are generally reached during July and lows during January.

Rain is the most common form of precipitation, but snowfalls occur regularly during the winter. Hail may fall during the summer thunderstorm season. The greatest volume of precipitation occurs in the winter, usually between the months of October and February. July is the driest month, averaging only 0.5 centimeters (cm) [0.2 inches (in)] of rainfall. The average annual precipitation falling at the Hanford Site is 15.9 cm (6.3 in) (Stone *et. al.*, 1983). This value was derived from HMS data gathered between the years 1912 through 1980.

Windblown dust is commonly associated with strong winds that regularly occur at the Hanford Site. Wind speeds average 10 to 12 km per hour (6 to 7 mi/h) in winter and 13 to 17 km/h (8 to 10 mi/h) during the summer months. The strongest observed winds have speeds measuring up to 130 km/h (80 mi/h). Blowing dust originating on the site itself has been observed at wind speeds greater than 32 km/h (19 mi/h). Dust entrained offsite and carried onto Hanford has been observed at wind speeds as low as 7 km/h (4 mi/h).

The mean annual rate of potential evapotranspiration for the region has been estimated at approximately 74 cm (29 in). The estimated rate of mean annual actual evapotranspiration is approximately 18 cm (7 in) (U.S. Weather Bureau and Soil Conservation Service, 1962). The rate of annual actual evapotranspiration, then, typically approximates the rate of annual precipitation for vegetated sites, which is not uncommon for semiarid areas.

2.2 GEOLOGY

Regional and local geologic settings are summarized in the following paragraphs. The discussion of local geology emphasizes topics that may have direct bearing on the descriptions of contaminant transport in the environment and on the development of remedial alternatives as presented later in this document. An exhaustive presentation of the regional and local geology can be found in DOE/RL-90-18, and Gaylord and Poeter, 1991.

2.2.1 Regional Geology

The Hanford Site is located in the Pasco Basin, a topographic and structural basin situated in the northern portion of the Columbia Plateau. The plateau is divided into three general structural subprovinces: the Blue Mountains; the Palouse; and, the Yakima Fold Belt (Tolan and Reidel, 1989). The Hanford Site is located near the junction of the Yakima Fold Belt and the Palouse subprovinces. A generalized geologic structural map is included as figure 2-1.

The 1100 Area is located along the southeastern margin of the Hanford Site, adjacent to the Columbia River. This area is similar to much of the rest of the site, which consists of a two-tiered stratigraphy of basalt/basalt-related volcanic and sedimentary rocks and suprabasalt sedimentary deposits. The principal units at the Hanford Site are (from oldest to youngest): Miocene Columbia River Basalt Group (CRBG); Miocene Ellensburg Formation; Miocene-Pliocene Ringold Formation; the informally defined Plio-Pleistocene clastic sedimentary unit; Pleistocene early "Palouse" soil; Pleistocene pre-Missoula gravels; the Pleistocene Hanford formation; and, Holocene eolian surficial deposits. The CRBG and Ellensburg Formation are included within the basalt/basalt-related deposits while all others are included within suprabasalt deposits.

Of the regional stratigraphic units listed above, only the CRBG, the Ringold Formation, the Hanford formation, and the eolian surficial deposits have been identified within the 1100-EM-1 Operable Unit.

2.2.2 Local Geology

The interpretation and description of the geology of the 1100-EM-1 Operable Unit is based primarily on previous studies in adjacent areas and on geologic logs of monitoring wells installed during both phases of the RI. Selected geohydrologic and groundwater quality studies of the 300 Area (Lindberg and Bond, 1979; Schalla, *et al.*, 1988; Gaylord and Poeter, 1991) provide descriptions of the suprabasalt stratigraphic units within approximately 1.6 km (1 mi) of HRL. When available, geologic logs for selected previously-existing wells located near the Operable Unit (Newcomb, *et al.*, 1972; Summers and Schwab, 1977; Fecht and Lillie, 1982; CWC-HDR, Inc., 1988; Geology Section, WHC [Technical Memo 81232-90-042 to S. Clark, WHC] May 11, 1990) were also consulted.

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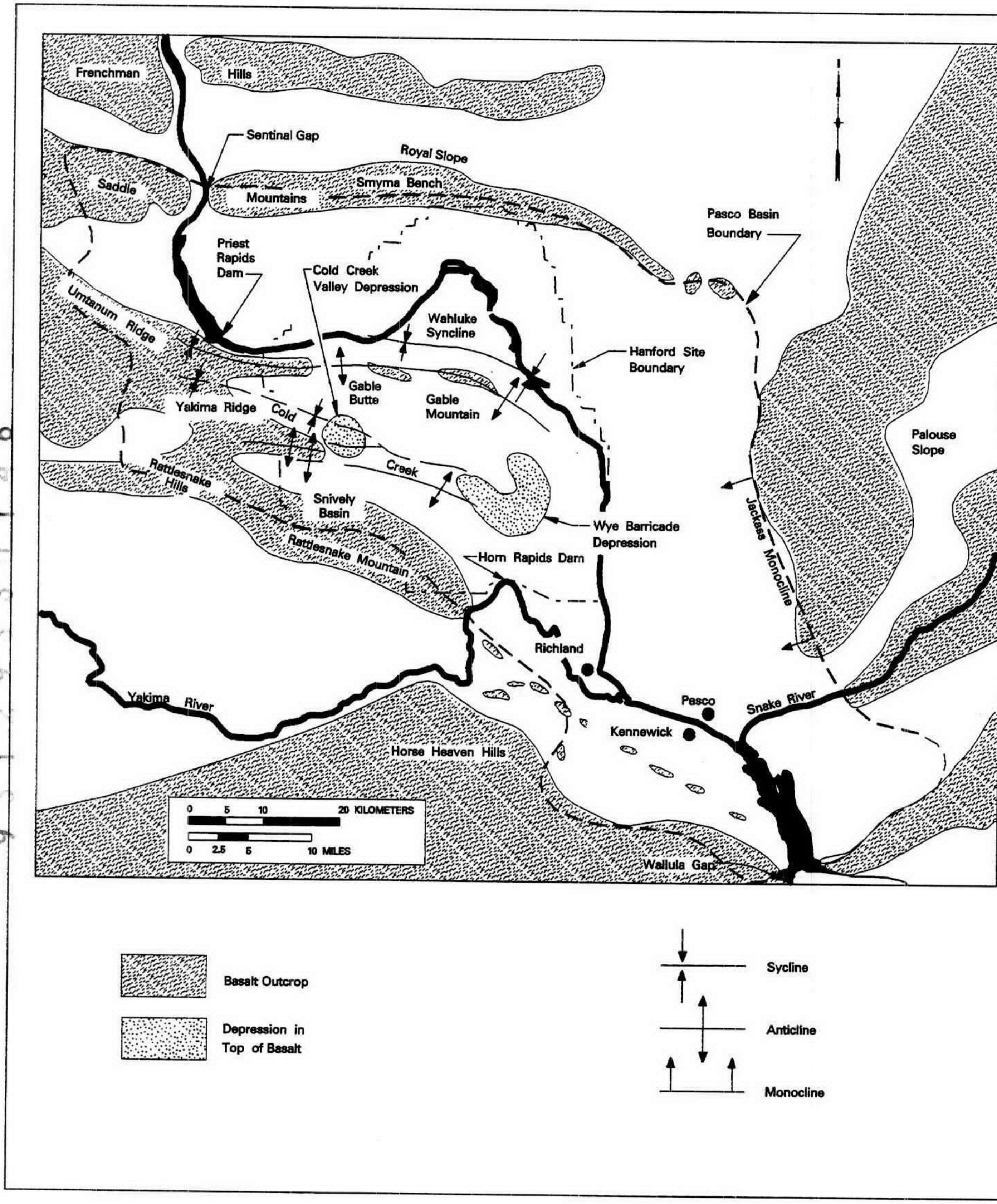


Figure 2–1. Geologic Structures of the Pasco Basin and the Hanford Site.

2.2.2.1. Structural Geology and Tectonic Setting. The Columbia Plateau is a part of the North American continental plate and is situated in the back-arc east of the Cascade Range. The plateau is bounded on the north by the Okanogan Highlands, on the east by the Northern Rocky Mountains and Idaho Batholith, and on the south by the High Lava Plains and Snake River Plain.

The Columbia River Basalts within the vicinity of 1100-EM-1, as interpreted by Myers and Price (1979), are folded into a broad, gentle, northwest-trending syncline; the Pasco syncline. The 1100-EM-1 subunits are located near the axis of this syncline, on its gently-sloping western flank. The Pasco syncline slopes gently northwestward toward a flat structural low referred to as the Wye Barricade depression (DOE/RL-88-23), where it loses definition. The geologic structure of the Ringold and Hanford formations has not been identified in the area of the 1100-EM-1 Operable Unit.

2.2.2.2 Local Stratigraphy. A generalized stratigraphic column for the 1100-EM-1 Operable Unit is shown in figure 2-2. Information obtained from the drilling of 22 soil borings and 23 groundwater monitoring wells during the 1100-EM-1 Operable Unit RI, and five groundwater monitoring wells installed between the 1100 Area and the North Richland well field in 1988 (Bryce and Goodwin, 1989) was used to develop the idealized stratigraphic column depicted.

The shallow depth of these borings and wells pose substantial limitations on the reliability of the estimates for the actual depth, thickness, and characteristics of the lower portion of the Ringold Formation beneath the 1100-EM-1 Operable Unit. None of the borings extended through the suprabasalt strata to bedrock. The interpretation of the lower stratigraphic units on figure 2-2 is based primarily on a single log for a nearby, previously existing well that extends to the basalt; 10/28-10G1. This log is published in Newcomb, *et al.*, 1972, and DOE/RL-90-18.

A cross section identification map is provided in figure 2-3. Cross section A-A" (which runs north-south from the HRL to south of the 1171 Building) is shown in figure 2-4. Three east-west cross sections are also provided: B-B" (through HRL) in figure 2-5, and C-C" (near the 1100-2 and 1100-3 subunits) and D-D" (near the 1100-1 and 1100-4 subunits) in figure 2-6.

Geologic logs for the Phase II monitoring well boreholes are included in appendix A. It should be noted that the lithologies shown in the borehole logs are based on visual field estimates of grain-size distribution using the Wentworth grain-size scale, as modified by Folk (1954). Laboratory grain size analyses were not performed during the Phase II investigations. However, comparisons of Phase II field classifications with Phase I laboratory classifications of soil types encountered during monitoring well installations revealed no unusual divergence.

Tables 2-1 through 2-4 list the depths and elevations of the stratigraphic units identified in the borings advanced and wells constructed during both phases of the 1100-EM-1 RI. Locations of Phase I and Phase II monitoring wells are presented on figures 2-7 and 2-8, respectively.

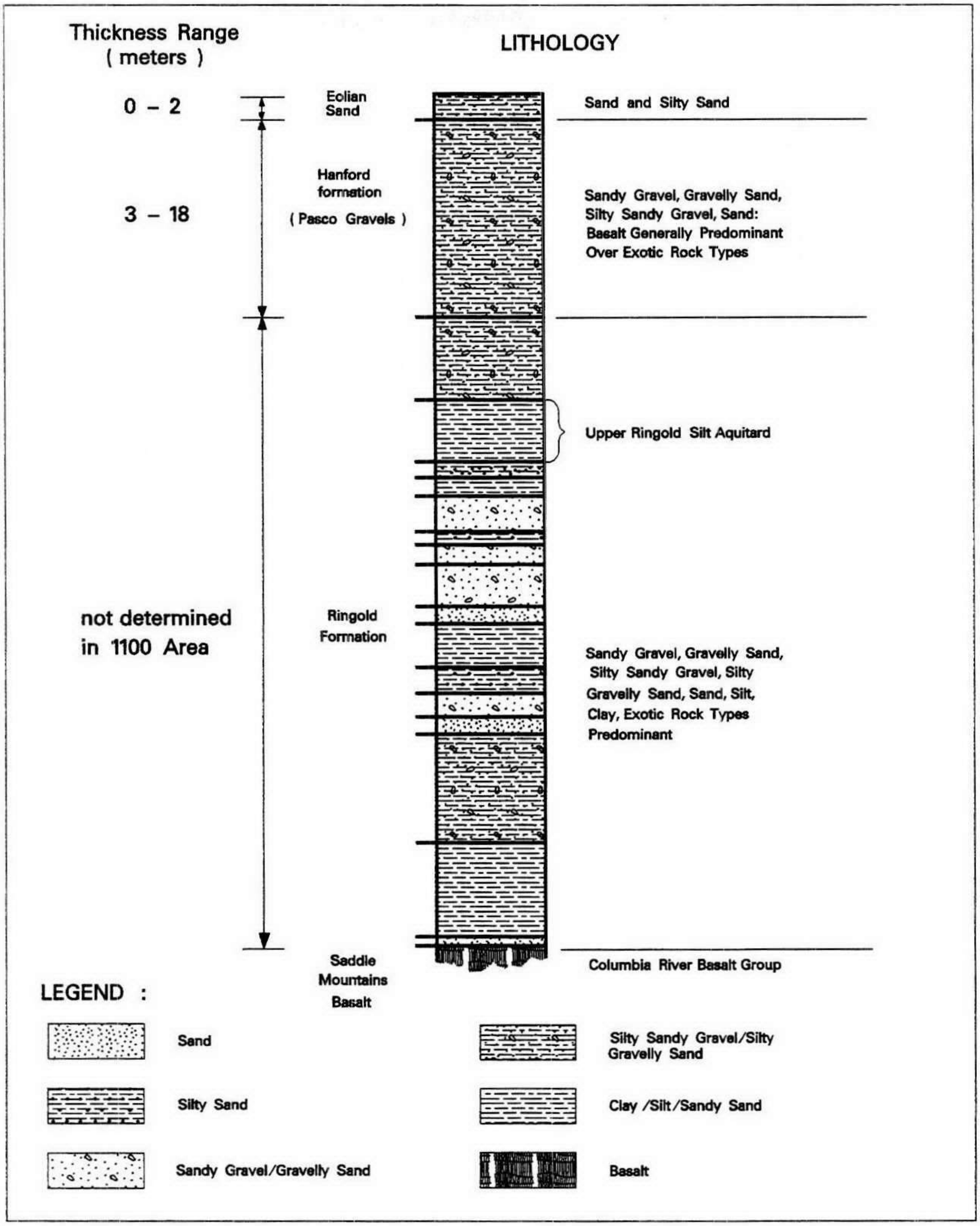
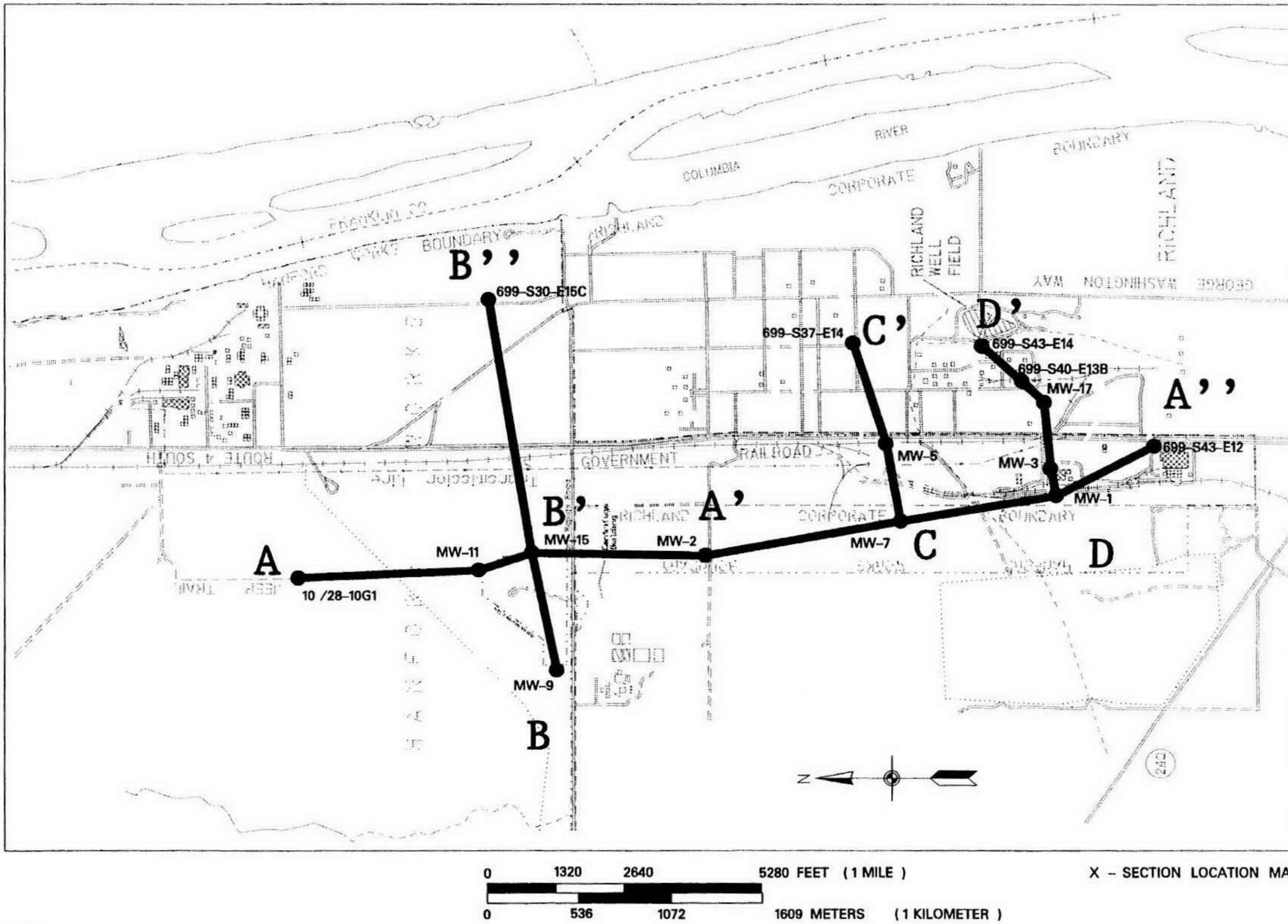


Figure 2-2. Generalized Suprabasalt Stratigraphic Column for the 1100-EM-1 Operable Unit

9 3 1 2 9 3 3 1 4 8



X – SECTION LOCATION MAP

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Fig. 2-3

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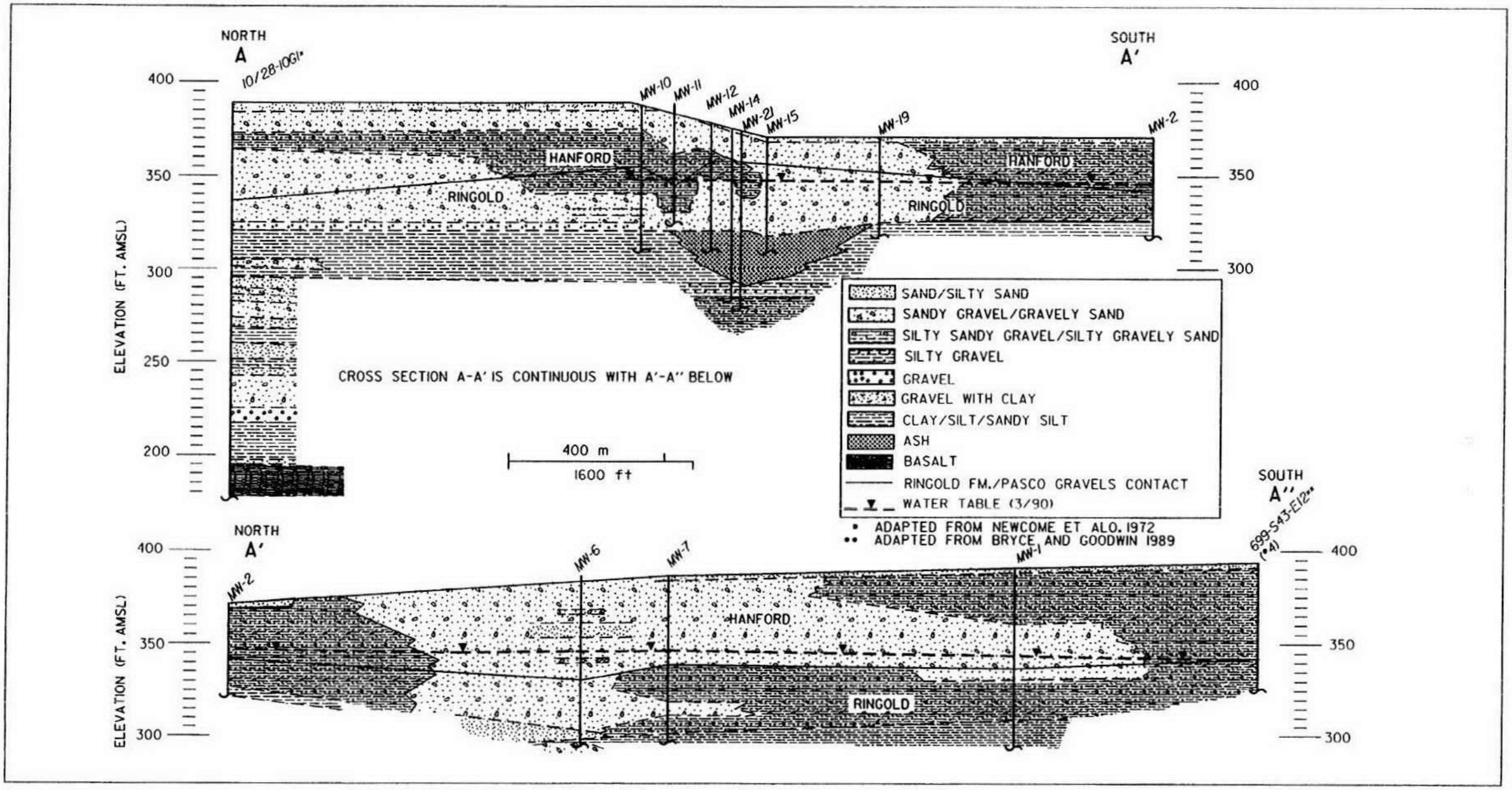

CROSS SECTION A-A''

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Figure 2-4

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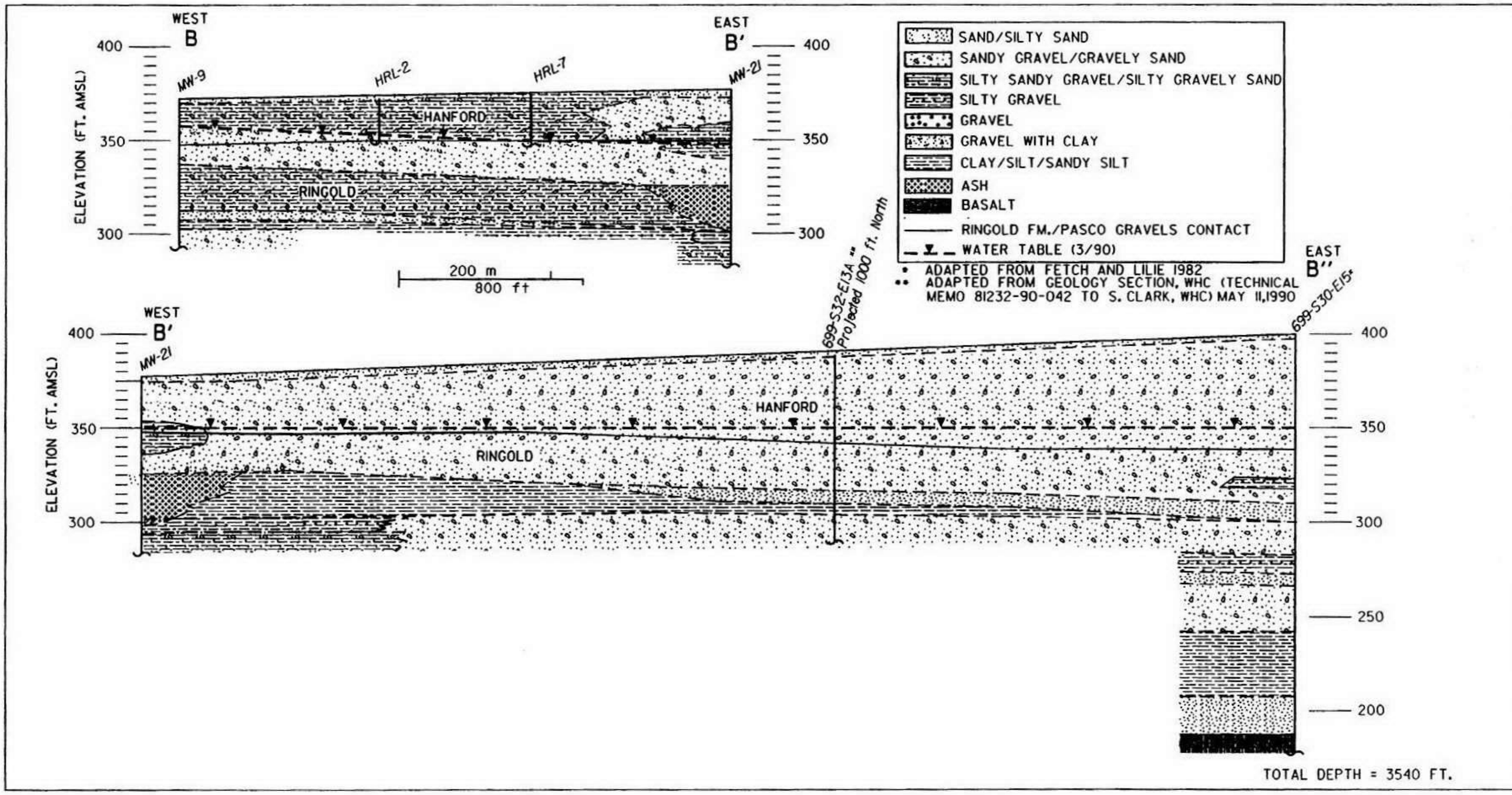

CROSS SECTION B-B''

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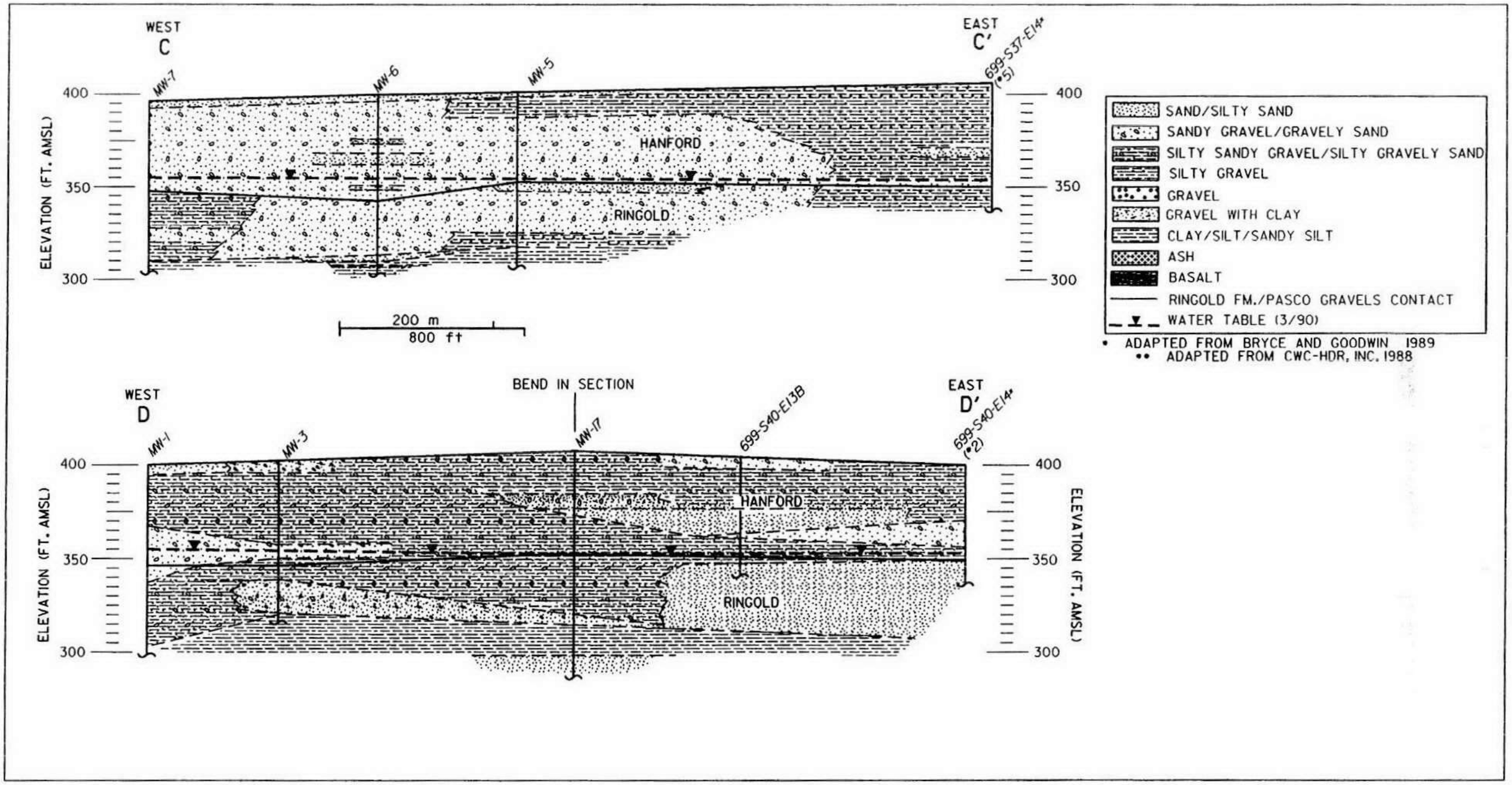
Figure 2-5



CROSS SECTION C-C ' AND D-D '

Figure 2-6

TABLE 2-1: Stratigraphic Data from Borehole Logs
Battery Acid Pit (1100-1), Antifreeze Tank Site (1100-4), Discolored Soil Site (UN-1100-6), and Ephemeral Pool

BORING	TOTAL DEPTH m(ft)	BORING ELEV. m(ft)	FILL THICKNESS m(ft)	EOLIAN SAND THICKNESS m(ft)	HANFORD FORMATION THICKNESS m(ft)	DEPTH TO TOP OF RINGOLD FM. m(ft)	TOP OF RINGOLD ELEV. m(ft)	DEPTH TO TOP OF SILT AQUITARD m(ft)	TOP OF SILT AQUITARD ELEV. m(ft)
Vadose Background									
BAP-2	13.88 (45.55)	121.21 (397.66)	N/A	0.30 (1.0)	Base of Eolian Sand to EOH	ND	ND	ND	ND
Vadose Zone Boring									
BAP-1	6.10 (20.0)	122.66 (402.42)	1.83 (6.0)	none	Base of Fill to EOH	ND	ND	ND	ND
ATS-1C	6.71 (22.0)	Not Available	3.75 * (12.3*)	none	Base of Fill to EOH	ND	ND	ND	ND
Monitoring Wells									
MW-1	28.65 (94.0)	121.44 (398.43)	N/A	0.58 (1.9)	16.03 (52.6)	16.61 (54.5)	104.83 (343.9)	26.97 (88.5)	94.47 (309.9)
MW-3	25.52 (83.74)	122.53 (402.0)	N/A	none	18.33 (60.14)	18.44 (60.5)	104.09 (341.5)	23.96 (78.6)	98.57 (323.4)
MW-17	38.10 (125.0)	124.24 (407.62)	N/A	none	17.07 (56.0)	17.07 (56.0)	107.17 (351.6)	27.58 (90.5)	96.66 (317.1)

NOTES:
1. EOH - End of Hole.
2. N/A - Not Applicable.
3. ND - No Data due to Shallow Depth of Boring.
4. * - 0.11 m (0.35 ft) of Blacktop Asphalt at Ground Surface.

9312930154

TABLE 2-2: Stratigraphic Data from Borehole Logs
Paint and Solvent Pit (1100-2)

BORING	TOTAL DEPTH m(ft)	BORING ELEV. m(ft)	FILL THICKNESS m(ft)	EOLIAN SAND THICKNESS m(ft)	HANFORD FORMATION THICKNESS m(ft)	DEPTH TO TOP OF RINGOLD FM. m(ft)	TOP OF RINGOLD ELEV. m(ft)	DEPTH TO TOP OF SILT AQUITARD m(ft)	TOP OF SILT AQUITARD ELEV. m(ft)
Vadose Background									
DP-7	12.50 (41.0)	119.65 (392.54)	N/A	0.46 (1.5)	Base of Eolian Sand to EOH	ND	ND	ND	ND
Vadose Zone Borings									
DP-4	6.10 (20.0)	120.15 (394.19)	2.16 (7.1)	none	Base of Fill to EOH	ND	ND	ND	ND
DP-5	6.10 (20.0)	120.22 (394.43)	4.88 (16.0)	none	Base of Fill to EOH	ND	ND	ND	ND
DP-6	6.10 (20.0)	120.31 (394.71)	not identified	none	To EOH	ND	ND	ND	ND
DP-9	12.13 (39.8)	119.68 (392.65)	1.22 (4.0)	none	10.82 (35.5)	12.04 (39.5)	107.64 (353.15)	ND	ND
Monitoring Wells									
MW-4	20.51 (67.29)	122.35 (401.40)	N/A	1.07 (3.5)	15.09 (49.5)	16.15 (53.0)	106.19 (348.4)	ND	ND
MW-5	27.02 (88.65)	122.40 (401.57)	N/A	0.91 (3.0)	14.94 (49.0)	15.85 (52.0)	106.55 (349.6)	26.49 (86.9)	95.91 (314.7)
MW-6	27.74 (91.0)	120.70 (396.0)	N/A	0.55 (1.8)	16.98 (55.7)	17.53 (57.5)	103.17 (338.5)	25.9 (85.0)	94.79 (311.0)
MW-7	27.22 (89.3)	120.46 (395.20)	N/A	1.14 (3.75)	13.91 (45.7)	15.06 (49.4)	105.40 (345.8)	26.06 (85.5)	94.40 (309.7)
MW-18	21.06 (69.1)	121.84 (399.74)	N/A	0.61 (2.0)	14.48 (47.5)	15.09 (49.5)	106.75 (350.24)	ND	ND

NOTES:
1. EOH – End of Hole.
2. N/A – Not Applicable.
3. ND – No Data due to Shallow Depth of Boring.

TABLE 2-3: **Stratigraphic Data from Borehole Logs Antifreeze and Degreaser Pit (1100-3)**

BORING	TOTAL DEPTH m(ft)	BORING ELEV. m(ft)	FILL THICKNESS m(ft)	EOLIAN SAND THICKNESS m(ft)	HANFORD FORMATION THICKNESS m(ft)	DEPTH TO TOP OF RINGOLD FM. m(ft)	TOP OF RINGOLD ELEV. m(ft)	DEPTH TO TOP OF SILT AQUITARD m(ft)	TOP OF SILT AQUITARD ELEV. m(ft)
Vadose Background									
DP-7	12.50 (41.0)	119.65 (392.54)	N/A	0.46 (1.5)	Base of Eolian Sand to EOH	ND	ND	ND	ND
Vadose Zone Borings									
DP-1	6.10 (20.0)	117.57 (385.74)	not identified	none	To EOH	ND	ND	ND	ND
DP-2	6.10 (20.0)	116.99 (383.84)	1.6 (5.3)	none	Base of Fill to EOH	ND	ND	ND	ND
DP-3	6.10 (20.0)	118.13 (387.58)	not identified	none	To EOH	ND	ND	ND	ND
DP-8	10.36 (34.0)	117.81 (386.51)	not identified	none	To EOH	ND	ND	ND	ND
Monitoring Wells									
MW-4	20.51 (67.29)	122.35 (401.40)	N/A	1.07 (3.5)	15.09 (49.5)	16.15 (53.0)	106.19 (348.4)	ND	ND
MW-5	27.02 (88.65)	122.40 (401.57)	N/A	0.91 (3.0)	14.94 (49.0)	15.85 (52.0)	106.55 (349.6)	26.49 (86.9)	95.91 (314.7)
MW-6	27.74 (91.0)	120.70 (396.0)	N/A	0.55 (1.8)	16.98 (55.7)	17.53 (57.5)	103.17 (338.5)	25.9 (85.0)	94.79 (311.0)
MW-7	27.22 (89.3)	120.46 (395.20)	N/A	1.14 (3.75)	13.91 (45.7)	15.06 (49.4)	105.40 (345.8)	26.06 (85.5)	94.40 (309.7)

NOTES:
1. EOH – End of Hole.
2. N/A – Not Applicable
3. ND – No Data due to Shallow Depth of Boring.

TABLE 2-4: Stratigraphic Data from Borehole Logs
Horn Rapids Landfill (1 of 3)

BORING	TOTAL DEPTH m(ft)	BORING ELEV. m(ft)	FILL THICKNESS m(ft)	EOLIAN SAND THICKNESS m(ft)	HANFORD FORMATION THICKNESS m(ft)	DEPTH TO TOP OF RINGOLD FM. m(ft)	TOP OF RINGOLD ELEV. m(ft)	DEPTH TO TOP OF SILT AQUITARD m(ft)	TOP OF SILT AQUITARD ELEV. m(ft)
Vadose Background									
HRL-1	5.67 (18.6)	112.71 (369.78)	N/A	0.30 (1.0)	Base of Eolian Sand to EOH	ND	ND	ND	ND
Vadose Zone Borings									
HRL-2	7.71 (25.3)	114.34 (375.13)	N/A	0.91 (3.0)	6.10 (20.0)	7.01 (23.0)	107.33 (352.1)	ND	ND
HRL-3	7.80 (25.6)	114.63 (376.07)	N/A	0.61 (2.0)	Base of Eolian Sand to EOH	ND	ND	ND	ND
HRL-4	7.77 (25.5)	114.48 (375.58)	not identified	none	To EOH	ND	ND	ND	ND
HRL-5	7.80 (25.6)	114.40 (375.33)	not identified	none	To EOH	ND	ND	ND	ND
HRL-6	8.47 (27.8)	114.95 (377.12)	not identified	none	To EOH	ND	ND	ND	ND
HRL-7	7.92 (26.0)	114.31 (375.04)	not identified	none	6.92 (22.7)	6.92 (22.7)	102.39 (352.3)	ND	ND
HRL-8	8.63 (28.3)	114.73 (376.40)	red brick frags. 6.31 to 6.95 (20.7 to 22.8)	none	Base of Fill to EOH	ND	ND	ND	ND
HRL-9	8.23 (27.0)	114.16 (374.54)	not identified	none	3.32 (10.9)	3.32 (10.9)	110.84 (363.6)	ND	ND

9 3 1 2 9 3 3 0 1 5 7

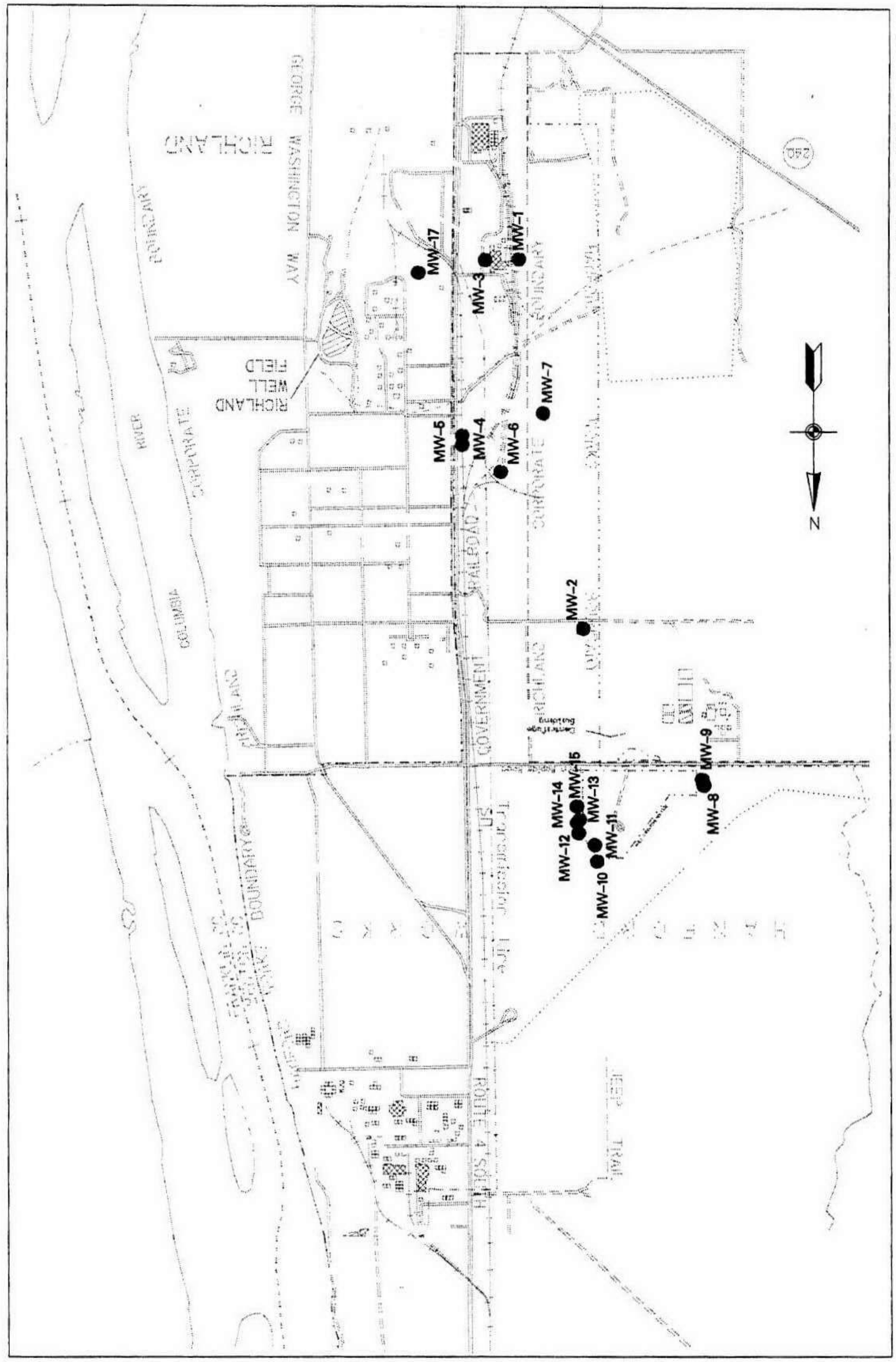
TABLE 2-4: Stratigraphic Data from Borehole Logs
Horn Rapids Landfill (2 of 3)

BORING	TOTAL DEPTH m(ft)	BORING ELEV. m(ft)	FILL THICKNESS m(ft)	EOLIAN SAND THICKNESS m(ft)	HANFORD FORMATION THICKNESS m(ft)	DEPTH TO TOP OF RINGOLD FM. m(ft)	TOP OF RINGOLD ELEV. m(ft)	DEPTH TO TOP OF SILT AQUITARD m(ft)	TOP OF SILT AQUITARD ELEV. m(ft)
Vadose Zone Borings continued									
HRL-10	10.5 (34.5)	116.24 (381.37)	discoloration @ 5.28 (19.1)	none	Base of Fill to EOH	ND	ND	ND	ND
Monitoring Wells									
MW-8	10.39 (34.08)	113.27 (371.62)	N/A	1.07 (3.5)	6.86 (22.5)	7.92 (26.0)	105.34 (345.6)	ND	ND
MW-9	24.8 (81.4)	113.34 (371.86)	N/A	1.07 (3.5)	7.59 (24.9)	8.66 (28.4)	104.69 (343.5)	10.73 (35.3)	102.61 (336.7)
MW-10	20.57 (67.5)	118.59 (389.09)	N/A	0.61 (2.0)	10.06 (33.0)	10.67 (35.0)	107.93 (354.1)	19.51 (64.0)	99.09 (325.1)
MW-11	17.83 (58.5)	118.47 (388.69)	N/A	0.82 (2.7)	12.28 (40.3)	13.11 (43.0)	105.37 (345.7)	ND	ND
MW-12	18.04 (59.17)	116.17 (381.14)	N/A	1.22 (4.0)	6.40 (21.0)	7.62 (25.0)	108.55 (356.1)	17.37* (57.0*)	98.8* (324.1*)
MW-13	13.41 (44.0)	115.78 (379.85)	N/A	none	7.62 (25.0)	7.62 (25.0)	108.16 (354.9)	ND	ND
MW-14	18.44 (60.5)	115.83 (380.01)	N/A	0.15 (0.5)	6.55 (21.5)	6.71 (22.0)	109.12 (358.0)	16.34* (53.6*)	99.49* (326.4*)
MW-15	16.60 (54.47)	115.04 (377.43)	N/A	0.30 (1.0)	6.40 (21.0)	6.71+ (22.0+)	108.34+ (355.4+)	15.82* (51.9*)	99.22* (325.5*)
MW-19	16.46 (54.0)	117.21 (384.56)	N/A	0.61 (2.0)	7.92 (26.0)	8.53 (28.0)	108.68 (356.56)	15.85 (52.0)	101.36 (332.56)

TABLE 2-4: **Stratigraphic Data from Borehole Logs**
Horn Rapids Landfill (3 of 3)

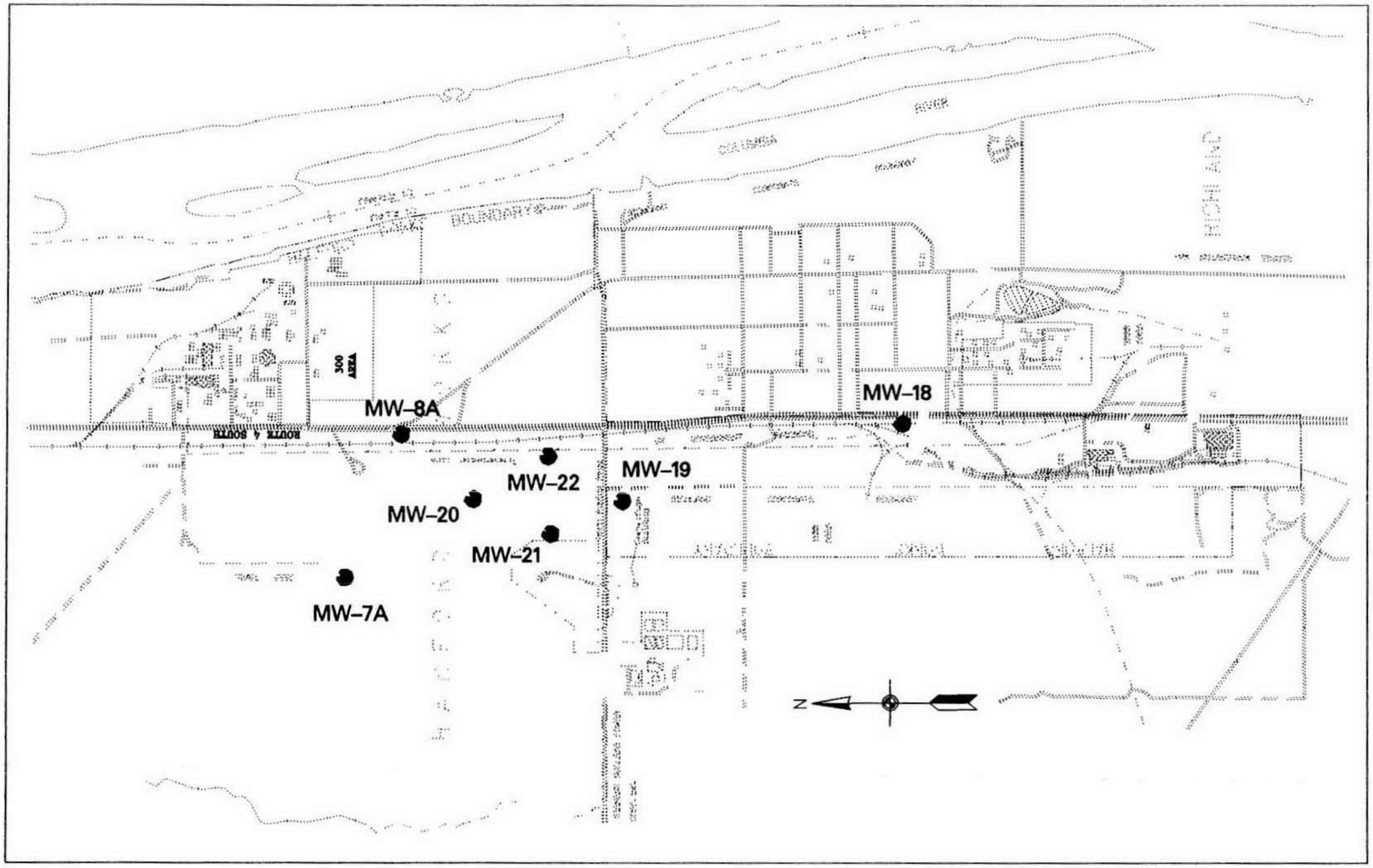
BORING	TOTAL DEPTH m(ft)	BORING ELEV. m(ft)	FILL THICKNESS m(ft)	EOLIAN SAND THICKNESS m(ft)	HANFORD FORMATION THICKNESS m(ft)	DEPTH TO TOP OF RINGOLD FM. m(ft)	TOP OF RINGOLD ELEV. m(ft)	DEPTH TO TOP OF SILT AQUITARD m(ft)	TOP OF SILT AQUITARD ELEV. m(ft)
Monitoring Wells									
MW-20	20.64 (67.7)	116.88 (383.45)	N/A	1.68 (5.5)	6.86 (22.5)	8.53 (28.0)	108.34 (355.45)	20.12* (66.0*)	96.76* (317.45*)
MW-21	29.26 (96.0)	115.66 (379.45)	N/A	0.91 (3.0)	9.30 (30.5)	10.21 (33.5)	105.45 (345.95)	23.62 (77.5)	92.03 (301.95)
MW-22	19.20 (63.0)	117.37 (385.07)	N/A	0.61 (2.0)	10.52 (34.5)	11.13 (36.5)	106.24 (348.57)	17.68* (58.0*)	99.69* (327.07*)
W-7A	17.77 (58.3)	118.26 (388.00)	N/A	0.61 (2.0)	9.51 (31.2)	10.12 (33.2)	108.14 (354.80)	ND	ND
W-8A	16.70 (54.8)	117.71 (386.19)	N/A	1.22 (4.0)	12.50 (41.0)	13.72 (45.0)	103.99 (341.19)	ND	ND

NOTES:
1. EOH – End of Hole.
2. N/A – Not Applicable.
3. ND – Not Determined due to shallow depth of boring.
4. + – Ringold contact based on visual examination of physical samples in the WHC Sample Library.
5. * – Measurement on top of volcanic ash layer.



Phase I Monitoring Wells Location Map

Fig. 2-7.



Phase II Monitoring Wells Location Map

0 05 Km. 1 KILOMETER

0 0.5 MILE 1 MILE

Fig. 2–8

2.2.2.2.1 Columbia River Basalt Group--The CRBG is characterized by a thick sequence of tholeiitic, continental flood basalts of Miocene age. These flows cover an area of more than 163,700 km^2 (63,000 mi^2) in Washington, Oregon, and Idaho, and have an estimated volume of about 174,356 km^3 (40,800 mi^3) (Tolan *et al.*, 1989). Isotopic age determinations indicate basalt flows were erupted from approximately 17 to 6 million years before present, with >98 percent of this volume extruded between 17 and 14.5 million years before present (Reidel *et al.*, 1989).

The Columbia River Basalt flows were erupted from north to northwest trending fissures or linear vent systems in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson *et al.*, 1979). The CRBG is formally subdivided into five formations (from oldest to youngest): Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Of these, only the Picture Gorge Basalt is not known to be present in the Pasco Basin. The Saddle Mountains Basalt is divisible into the Ice Harbor, Elephant Mountain, Pomona, Esquatzel, Asotin, Wilbur Creek, and Umatilla members and forms the uppermost basalt across most of the Pasco Basin. The Elephant Mountain member is the uppermost flow beneath most of the Hanford Site except north of the 200 Area where erosion has removed most of the younger flows down to the Umatilla member, and near the 300 Area where the topmost unit is the Ice Harbor Basalt. Erosion has also exposed the Wanapum and Grande Ronde Basalts on the anticlinal ridge crests bounding the Pasco Basin.

Bedrock geology was not considered during the development of remediation alternatives for this project and will not be discussed further.

2.2.2.2.2 Ringold Formation--The Ringold Formation consists of semi-indurated clay, silt, pedogenic mud, fine- to coarse-grained sand, cobbles, and gravel that usually are divided into: (1) gravel, sand, and paleosols of the basal unit; (2) clay and silt of the lower unit; (3) gravel of the middle unit; (4) mud and lesser sand of the upper unit; and (5) basalt detritus of the fanglomerate unit (Newcomb, 1958; Newcomb, *et al.*, 1972; Myers and Price, 1979; Bjornstad, 1984; DOE/RL-88-23). Ringold strata also have been divided on the basis of facies types (Tallman, *et al.*, 1981) and fining-upwards sequences (PSPL, 1982). All of these stratigraphic divisions are of limited use as they are too generalized to account for marked local stratigraphic variations or are defined sufficiently only for small areas (Lindsey and Gaylord, 1990).

Data available for the characterization of the Ringold Formation in the vicinity of the 1100-EM-1 Operable Unit are limited. Of the monitoring wells installed and soil borings sampled during the RI, 27 penetrated the Ringold Formation to depths ranging from 7.7 to 38 meters (m) [25.3 to 125 feet (ft)] below the ground surface. The data show the upper portion of the Ringold Formation in the vicinity of the Operable Unit to consist primarily of interfingering sandy gravels, gravelly sands, silty sandy gravels, and silty gravelly sands, with discontinuous sand lenses. Data from the deeper monitoring wells show that these coarse-grained sediments are underlain by finer-grained facies comprised of silt, clay, sandy silt, and sand.

Gravels and sands in the upper portion of the Ringold Formation underlying the 1100-EM-1 Operable Unit are poorly to moderately consolidated, and are calcareous in some wells. Sorting of the gravelly horizons is generally poor, whereas the sand units are typically well sorted. Sands are commonly angular to subangular, micaceous, and quartzitic. The gravels and sands are generally brown-gray to gray-brown, with olive grays and olive browns occurring locally. The lithologies of gravel clasts indicate that they were derived from granitic and metamorphic rocks located outside the Pasco Basin. Within the gravel horizons, however, basaltic gravels and sands predominate locally, reflecting upstream erosion in basaltic terrain traversed by the Columbia River.

The fine-grained sediments underlying the coarse-grained facies are moderately consolidated, and clayey horizons are generally plastic. The uppermost fine-grained unit consists of a brown to yellow-brown to olive silt-to-clay horizon that was encountered at most of the monitoring wells installed throughout the 1100-EM-1 Operable Unit. In the few wells where the entire silty unit was penetrated, the thickness varies. In monitoring wells MW-9 and MW-21, at the HRL, and in MW-17, east of the 1171 Building, the silty unit is approximately 10, 1, and 5.5 m (33, 3.4, and 18 ft) thick, respectively. This silty layer acts as an aquitard within the 1100-EM-1 Operable Unit, separating the unconfined aquifer from the confined aquifer.

The elevation of the top of the uppermost fine-grained Ringold Formation silt unit varies across the operable unit. As shown in north-south cross section A-A" (see figure 2-4), the fine-grained facies decreases in elevation southward, from approximately 99 to 103 m (324 to 337 ft) at HRL to approximately 94 m (310 ft) in the vicinity of monitoring well MW-1, west of the 1171 Building. There is a 7 m (23 ft) decrease in elevation of the top of the silt between MW-2, where the elevation is 101 m (333 ft), and MW-6 and MW-7 to the south, where the elevations are approximately 94 m (310 ft). As shown in east-west cross section D-D" (see figure 2-6), there is a 4 m (13 ft) increase in elevation of the top of the silt between MW-1, west of the 1171 Building, and MW-3, located approximately 168 m (550 ft) to the east.

The clayey silt unit in the vicinity of the 1100-EM-1 Operable Unit has been tentatively identified as a paleosol, based on the absence of bedding, the massive appearance, a pattern of disaggregation typical of paleosols in the Ringold Formation throughout the Hanford Site, and the mixing of silt- and clay-sized grains which suggests bioturbation. Based on current knowledge of the Ringold depositional system, this paleosol is inferred to have formed in an overbank setting where muds deposited by floods were subjected to pedogenic alteration. Similar fine-grained facies are reported in the Ringold Formation in many borehole logs for existing wells in and near the Operable Unit. In well 10/28-10G1, north of HRL, an uppermost clay horizon is approximately 5 m (17 ft) thick (Newcomb *et al.*, 1972). However, the quality of many of the existing borehole logs is such that the fine-grained sediments noted can not be definitively correlated with those present in the monitoring wells constructed for the 1100-EM-1 RI.

Available data precludes determining whether the fine-grained Ringold sediments are laterally continuous over a broad area. Because of its considerable thickness in MW-9, MW-17, and 10/28-10G1, the fine-grained facies is interpreted to be laterally continuous within and near the Operable Unit (see figure C-2). However, the fine-grained facies appears have been locally eroded prior to deposition of the overlying Ringold Formation gravels, creating an irregular erosional surface at the top, and the silt unit may have been completely eroded in some areas not investigated by soil borings.

The probable depositional environment of the Ringold Formation beneath the 1100-EM-1 Operable Unit is fluvial, in which the coarse-grained facies are interpreted to be high-energy, meandering river channel deposits, and the fine-grained facies are interpreted to be overbank and lacustrine floodplain deposits.

In MW-12, MW-14, MW-15, MW-21, and MW-22, east of HRL, a distinctive ash layer was encountered at an approximate elevation of 99 m (325 ft) (see figures 2-3 and 2-4). The ash was microscopically examined and shown to consist of white, angular-to-subangular, glassy, silt-sized grains showing no evidence of alteration other than mechanical breakage. Dark accessory mineral grains, probably heavy minerals and other mafic grains, constitute less than 1 percent of the ash. Some of the ash grains appear to be fragments of bubble-walls (glass containing gas bubbles entrapped during solidification). With the exception of a few very-thin layers of fine sand or of staining, bedding is indiscernible in core barrel and split spoon samples.

A thickness of 7.04 m (23.1 ft) of ash was penetrated in MW-21. Because all other wells that encountered the ash were completed prior to reaching the base of the unit, the overall geometry of the deposit is uncertain. No ash of a comparable thickness or in a similar stratigraphic position has been reported from the Ringold Formation elsewhere beneath the Hanford Site. The lateral extent of the ash appears to be very limited, in that the three closest wells to the south, west, and north (MW-2, MW-9, and MW-10, respectively) contained massive, brown-to-tan silt and clay comprising the silt aquitard horizon mentioned above (see figures 2-3 and 2-4, and figure C-4) at the same elevation as the ash. Ash is not reported to occur in the same stratigraphic position to the northeast in the 300 Area (Lindberg and Bond, 1979; Schalla *et al.*, 1988), and available existing borehole logs to the east and southeast do not report an ash unit in this stratigraphic position.

The depositional environment of the ash interval is unclear. The subangularity of the ash grains, the lack of abundant bubble-wall shards, and the presence of minor sand stringers or staining suggests that some reworking by fluvial processes has occurred subsequent to deposition, presumably by air fall. However, the generally massive bedding and the lack of nonvolcanic material, as well as the absence of chemically weathered grains, suggests that reworking was not extensive.

The most-favored hypothesis to interpret the relationships between the environment of deposition of the ash and the apparently laterally continuous clayey silt paleosol is that they are separated by an erosional surface (disconformity). The clayey silt is tentatively interpreted to be a paleosol formed in an overbank setting where muds deposited by floods subsequently underwent pedogenic alteration. The absence of chemical weathering in the ash precludes it from being correlative with the paleosol. The ash unit is tentatively interpreted to be an air fall ash deposit of limited extent that was subsequently reworked by a fluvial system on a local erosional surface capping the clayey silt paleosol. The ash may have been transported to its present location by a nearby drainage, possibly the ancestral Yakima River, that drained the volcanic Cascade terrain. A relatively close source could account for the purity of the ash and the lack of major mechanical erosion resulting in only minor reworking of the ash.

The shallow depth of the monitoring wells constructed during the 1100-EM-1 RI precludes determining the nature and thickness of the lower portion of Ringold Formation beneath the 1100-EM-1 Operable Unit. Therefore, the overall thickness of the Ringold Formation has been estimated based on the assumption that the approximate of depth to the top of basalt is 59 m (195 ft) (Myers and Price, 1979), and that elevation of the top of the Ringold Formation ranges from 103 to 111 m (337 to 364 ft) (see figure C-1). Using these assumptions, the thickness of the Ringold Formation beneath the Operable Unit is estimated to range from approximately 44 to 52 m (142 to 169 ft). This thickness is consistent with the thickness of the Ringold Formation in the North Richland well field area, which is reported by CWC-HDR, Inc. (1988) to range from 30 to 46 m (100 to 150 ft). Total thickness of the Ringold Formation in test well 10/28-10G1, located approximately 1.3 km (0.7 mi) north of HRL, is reported by Newcomb *et al.*, (1972) to be approximately 44 m (144 ft). In the 300 Area, approximately 1.9 km (1 mi) northeast of HRL, the Ringold Formation is approximately 46 m (150 ft) thick (Lindberg and Bond, 1979).

The lithologic units in the upper portion of the Ringold Formation beneath the 1100-EM-1 Operable Unit, as recorded in the borehole logs for the groundwater monitoring wells constructed for the RI, are tentatively interpreted to be equivalent to the middle Ringold textural facies of Newcomb (1958) and Myers and Price (1979). It is also proposed that, based on the elevation of the middle and upper Ringold units exposed east of the Operable Unit along the Columbia River near White Bluffs, the upper portion of the middle Ringold unit and the upper Ringold unit of Newcomb (1958) and Myers and Price (1979) are not present beneath the Operable Unit, and have most likely been removed by erosion.

2.2.2.2.3 Hanford Formation--The informally defined Hanford formation is composed of uncemented pebble to boulder conglomerate and less commonly of fine- to coarse-grained sand, silt, and silty clay. The bulk of these sediments were derived during Pleistocene Missoula floods, though some are also attributed to pre-Missoula flood episodes (PSPL, 1982).

Extensive scouring associated with the Missoula flood deposits was responsible for the erosion of an approximately north-south oriented paleochannel that cuts across the western side of the 300 area, immediately northeast of the 1100-EM-1 Operable Unit (Lindberg and Bond, 1979). This channel, which was filled with coarse-grained, dominantly gravel detritus during Hanford time, merges with the modern Columbia River north of and at the extreme southern margin of the 300 Area.

The Pasco gravels are the dominant facies of the Hanford formation in the vicinity of the 1100-EM-1 Operable Unit. The distinction between the Pasco gravels and the Ringold Formation is generally made on the basis of mineralogy, grain size, weathering of basalt clasts, and cementation. Pasco gravels have a higher percentage of basaltic materials, and are generally coarser-grained and uncemented. Pasco gravel basalt clasts are commonly less weathered than basalt clasts in the Ringold Formation.

The Pasco gravels unconformably overlie the Ringold Formation at the 1100-EM-1 Operable Unit and consist of a variable mixture of boulders, cobbles, pebbles, sands, and silts. Most of the Pasco gravels can be classified as moderately to poorly sorted, unconsolidated sandy gravels to gravelly sands and silty sandy gravels. Sand lenses up to 2 m (7 ft) thick are present locally. The gravels are composed primarily of subrounded to rounded, unweathered basalt clasts with lesser amounts of mixed granitic and metamorphic lithologies. Calcium carbonate rinds occur on some gravel clasts and reworked caliche clasts are present locally . The sand fraction is angular to rounded and medium to coarse-grained, and contains from 20 to 90 percent basalt. The color ranges primarily from dark grays to dark browns, with lighter-brown materials locally present near the ground surface.

Within the 1100-EM-1 Operable Unit, the Pasco gravels range in thickness from approximately 7.6 m (25 ft) at HRL to 17 m (56 ft) in the vicinity of the 1171 Building. Within the groundwater monitoring wells constructed east of the 1100 Area, the thickness of the Pasco gravels was identified as approximately 15 m (50 ft) (Bryce and Goodwin, 1989).

The Pasco gravels were deposited during multiple Pleistocene glaciofluvial flood events on an irregular erosional surface of the Ringold Formation. The predominantly coarse-grained facies present beneath the 1100-EM-1 Operable Unit indicate that the area was within a main channel of these floods.

Lindberg and Bond (1979) have identified two cycles of graded bedding within the Pasco gravels at the 300 Area. They interpret each fining-upward sequence to represent deposition of coarse sediments during initial surges of flood waters. The finer sediments were deposited later as each flood surge diminished. The finer portion of the second, or upper, cycle is not present in the 300 Area, and Lindberg and Bond (1979) suggest that it may have been removed by erosion. These fining-upward sequences in the Pasco gravels were not recognized in the vicinity of the 1100-EM-1 Operable Unit.

2.2.2.2.4 Holocene Eolian Surficial Deposits--Holocene eolian deposits locally form a veneer that generally overlies the Hanford formation within the 1100-EM-1 Operable Unit. This veneer ranges from less than 0.3 m (1 ft) to more than 1.8 m (6 ft) in thickness. The deposits consist of wind-transported sand that was derived from reworked Hanford formation sediments. In some portions of the 1100-EM-1 Operable Unit, these sands form dunes with amplitudes exceeding 3 m (10 ft); the dune bordering UN-1100-6 subunit to the south has an amplitude of approximately 6 m (20 ft).

These sands are generally composed of brown, very fine- to medium-grained sand or silty sand. They are moderately to well sorted, contain from 10- to 80-percent mafic constituents, and commonly contain root hairs and plant material.

2.3 SURFACE WATER HYDROLOGY

A detailed characterization of surface water hydrology, regionally within the Pasco Basin and locally in the vicinity of the 1100-EM-1 Operable Unit, was presented in DOE/RL-90-18. With few exceptions, little new information is presented in this report to change the previous findings. Of note is the description and characterization of the Ephemeral Pool (see paragraph 3.6).

The 1100 Area is clearly not in the 100-year floodplain of either the Columbia or Yakima Rivers (Hanford Site National Environmental Policy Act (NEPA) Characterization, C.E. Cushing, PNL-6415 Revision 4, 1991). Based on the probable maximum flood (PMF) floodplain delineation in the referenced document and the relative magnitudes of the PMF and 500-year floods, the HRL and other subunits in the 1100 Area will not be inundated by floods having return periods less than 500 years. Although the floodplain of the 500-year event has not been formally defined for the Hanford area, predicted flows for the PMF and the 500-year flood are 40,000 cubic meters per second (cms) [1.4 million cubic feet per second (cfs)] and 15,000 cms (0.5 million cfs), respectively (Water Control Manual for McNary Lock and Dam, Columbia River, Oregon and Washington, U.S. Army Corps of Engineers, August 1989). The PMF floodplain delineation shows the low areas near the HRL being inundated, while the main body of the landfill and the subunits along Stevens Drive were not predicted to be within the PMF floodplain. The 500-year flood, being less than half as large as the PMF floodplain, would, therefore, not flood these same areas.

The topography within the 1100-EM-1 Operable Unit is generally flat, with no obvious drainage channels or ponds. The lack of well defined drainages, and the arid to semiarid climate, lead to the infiltration and evapotranspiration of moisture from virtually all surface waters. However, manmade ponds do exist near the 1100-EM-1 Operable Unit. To the southwest of HRL is the SPC facility. The lined ponds located at SPC are used for pretreatment of waste water. Two miles southeast of the HRL and to the east of the 1171 Building is the North Richland well field. The unlined ponds operated in the city well field are specifically intended to recharge the unconfined groundwater table with water pumped from the Columbia River. Water filtered in this manner is then extracted to satisfy seasonal and peak municipal demands.

2.4 HYDROGEOLOGY

A detailed description of the 1100-EM-1 Operable Unit hydrogeology was presented in DOE/RL-90-18 and is summarized, with updated information, in the following paragraphs. Pertinent additional information gathered subsequent to Phase I RI report, relating to the well inventory, observed groundwater levels, and hydraulic parameters for the saturated and unsaturated zone are discussed.

2.4.1 Monitoring Well Inventory

Twenty three groundwater monitoring wells were installed during the 1100-EM-1 RI. These wells were installed to provide additional groundwater sampling stations; to define geological and hydrogeological characteristics of the Operable Unit; and, in two instances (MW-3 and MW-8A), to define further the nature and extent of contamination in the soil column.

2.4.1.1 Phase I Monitoring Wells. A total of 16 wells were installed during the Phase I RI. Well installation occurred from November 1989 through February 1990. The cabletool drilling method was used to advance borings designated to receive well assemblies. All wells were constructed with stainless steel screens and casing. Well construction was performed in accordance with Washington State standards for resource protection wells [Washington Administrative Code (WAC)173-160-500]. Phase I well locations are presented on figure 2-7.

Laboratory analyses were conducted for the following soil physical parameters: grain-size distribution, moisture content of soils located above the local water table, and, in a few select cases, vertical permeability. Soil samples collected for chemical analysis were obtained only at MW-3. These samples were analyzed for Target Analyte List (TAL) and Target Compound List (TCL) parameters.

Drill cuttings and soil samples from each boring were logged by a professional geologist who noted details on stratigraphy, drilling method and characteristics, well construction, types and locations of downhole samples, and visual soil characteristics. Soil samples collected for physical analysis, and chemical analysis in the case of MW-3, were obtained at approximately 1.5-m (5-ft) intervals and at changes in soil composition. A detailed summary of the distribution of downhole soil samples; a summary of well completion information; summary borehole logs for each monitoring well installation; results of physical analyses of soil samples; and, soil chemical analytical results are contained in the appendixes of DOE/RL-90-18.

2.4.1.2 Phase II Monitoring Wells. Seven additional groundwater monitoring wells were installed during the Phase II RI. Well installation took place from January through July 1991. As during the Phase I installations, cabletool drilling was exclusively used to advance borings designated to receive well assemblies. Wells were constructed with stainless steel screens and casing. All construction was again performed according to Washington State standards for installation of resource protection wells (WAC 173-160-500). Location of the Phase II wells are provided on figure 2-8.

Laboratory analyses for the determination of physical soil parameters were not conducted during the Phase II RI. Soil samples collected for chemical analysis were obtained from well MW-8A. These samples were analyzed for TAL and TCL parameters.

Drill cuttings and soil samples from each boring were logged by a professional geologist who noted details on stratigraphy, drilling method and characteristics, well construction, types and locations of downhole samples, and visual soil characteristics.

Soil samples collected for chemical analysis were obtained at approximately 1.5 m (5 ft) intervals and at changes in soil composition. The distribution of downhole soil samples is provided on summary borehole logs provided in appendix A. A summary of well completion information is contained in table 2-5. Soil chemical analytical results are provided in appendix D.

2.4.2 Groundwater Levels

The more detailed definition of site hydrogeology provided by the Phase II RI data and the larger well inventory, confirms the basic description of groundwater occurrence and flow found in DOE/RL-90-18. Monthly potentiometric surface maps for March 1991 to June 1992 are found in appendix B of this document. Groundwater level elevations are provided in table 2-6. Additional maps for January 1990 through February 1991 were previously presented in the "Interim Groundwater Data Summary Report for the 1100-EM-1 Operable Unit for 1990," prepared for Westinghouse Hanford Company by Golder Associates, Inc., September 20, 1991, (Doc. No.903-1215) and are not included herein. All of these maps were prepared for the 1100-EM-1 Operable Unit from water level measurements taken in monitoring wells during the course of the RI. The purpose of these constructions was to refine the interpretation of groundwater flow directions, groundwater surface fluctuations, and relative groundwater flow velocities, discussed in DOE/RL-90-18. The maps include data gathered from the 300 Area and the SPC area (see paragraph 3.7).

The potentiometric surface maps show, for the observed period, the direction of groundwater flow in the unconfined aquifer and the range of groundwater level fluctuations. The direction of flow is from high pressure (high potentiometric head) towards the adjacent lower pressure (lower potentiometric head). On the maps, this is orthogonal to the contours in the down-gradient direction. Site groundwater flow and water table fluctuations are discussed in paragraph 2.4.3.2.

2.4.3 Hydrostratigraphy

The hydrostratigraphy within the 1100-EM-1 Operable Unit consists of the unsaturated vadose zone, an unconfined (water table) aquifer, a clayey silt aquitard, a confined aquifer, and a lower clayey silt to silty clay unit which essentially overlies bedrock. This basic hydrostratigraphy was used in the development of the groundwater model described in paragraph 6.4 and in appendix H. A generalized depiction of the hydrostratigraphic column is presented in figure 2-9.

2.4.3.1 Vadose Zone. The vadose zone consists predominantly of unsaturated interlayered sandy gravel, gravelly sand, and silty sandy gravel of the Hanford formation between the ground surface and the water table. It is the zone through which natural and anthropogenic recharge waters may migrate toward the groundwater.

Table 2-5: Completion Summary for the Phase II Monitoring Wells

Well ID	Installation Date (mo/yr)	Ground Surface Elevation (ft amsl)	Top of Screen Elevation (ft amsl)	Screen Length (ft)	Sand Pack Interval (ft amsl)	Screen Type	Aquifer
MW-7A	5/91	388.00	353.50	20.00	356.20 - 332.00	a	Unconfined
MW-8A	5/91	386.19	350.90	20.30	354.69 - 326.19	a	Unconfined
MW-18	1/91	399.74	357.74	20.00	360.44 - 333.44	a	Unconfined
MW-19	6/91	384.56	354.56	20.98	358.76 - 330.56	a	Unconfined
MW-20	6/91	383.45	359.35	21.00	362.55 - 318.85	a	Unconfined
MW-21	6/91	379.45	290.95	10.00	298.95 - 280.95	a	Confined
MW-22	6/91	385.07	355.07	20.40	358.07 - 325.07	a	Unconfined

NOTES:
1. a - 0.010 slot, stainless steel, wire wound screen.
2. A similar completion summary for the Phase I monitoring wells is provided in chapter 2 of the Phase I RI report (DOE/RL 90-18).

9 3 1 2 9 3 3 0 1 7 0

Table 2-6: 1100-EM-1 Operable Unit Monitoring Well Groundwater Levels

DATES

Groundwater Elevations (m)

Well ID	2/90	6/90	9/90	3/91	4/91	5/91	6/91	7/91	8/91	9/91	10/91	11/91	12/91	1/92	2/92	3/92	4/92	5/92	6/92	7/92	8/92	9/92
11-34-13	107.35	107.29	107.56	107.15	107.16	107.25	107.38	107.62	107.72	107.86	107.86	107.77	107.70	107.47	107.33	107.23	107.20	107.23	107.284	107.23	107.20	107.16
11-41-13C	107.30	107.62	107.72	106.75	107.15	108.38	108.53	108.59	108.66	108.75	108.46	107.96	107.41	106.96	107.02	106.99	107.10	107.36	107.253	107.34	107.15	107.50
30-45-16	105.80	106.41	106.06	105.34	105.61	106.33	106.54	NA	108.12	NA	NA	NA	NA	106.06	106.06	106.07	106.97	106.06	107.515	107.24	107.05	107.22
30-47-18B	104.42	105.57	103.40	104.63	105.29	105.36	105.19	104.85	105.00	104.08	104.44	104.02	104.02	103.94	103.66	103.91	103.80	104.43	104.483	103.69	103.34	103.42
S27-E14	104.67	105.52	103.88	104.79	105.36	105.61	105.35	104.58	104.43	103.98	104.12	104.14	104.52	104.17	103.92	104.05	104.39	NA	NA	NA	NA	NA
S29-E11 (MW-20)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	105.87	105.77	105.70	NA	105.56	105.64	105.741	105.76	106.31	105.25
S29-E12	105.36	105.86	105.42	105.35	105.40	105.24	105.79	105.73	105.65	105.60	105.60	106.32	105.47	105.33	105.24	NA	105.21	105.29	105.406	105.33	105.25	NA
S30-E10A (MW-10)	106.24	106.28	106.34	106.30	106.26	106.29	106.32	106.43	106.46	106.53	106.56	106.57	106.60	106.50	106.42	106.37	106.28	106.27	106.324	106.38	106.37	106.34
S30-E10B (MW-11)	106.40	106.39	106.49	106.42	106.40	106.42	106.45	106.55	106.60	106.68	106.71	NA	106.73	106.66	106.60	106.50	106.45	106.43	106.485	106.54	106.54	106.52
S30-E15A	104.67	105.65	103.84	104.76	105.21	105.39	104.88	104.83	104.96	104.17	104.34	104.26	104.39	104.26	103.96	103.97	104.22	104.62	104.729	104.14	103.65	103.64
S31-E10A (MW-12)	106.12	106.16	106.22	106.12	106.11	106.16	106.21	106.34	106.38	106.46	106.51	106.49	106.48	106.36	106.27	106.16	106.11	106.13	106.193	106.25	106.23	106.20
S31-E10B (MW-13)	106.34	106.34	106.43	106.34	106.31	106.35	106.38	106.51	106.56	106.56	106.70	106.70	106.69	106.59	106.51	106.41	106.36	106.35	106.415	106.47	106.46	106.44
S31-E10C (MW-14)	106.31	106.92	107.01	106.31	106.29	106.32	106.36	106.49	106.54	106.63	106.68	106.67	106.64	106.57	106.50	106.38	106.32	106.33	106.394	106.44	106.43	106.41
S31-E10D (MW-15)	106.28	106.28	106.37	106.28	106.26	106.29	106.34	106.46	106.51	106.60	106.65	106.65	106.64	106.52	106.43	106.34	106.29	106.30	106.354	106.41	106.40	106.37
S31-E10E (MW-21)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	106.50	106.42	106.32	NA	106.16	106.19	106.269	106.33	106.32	106.31
S31-E11 (MW-22)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	105.82	105.64	105.51	NA	105.51	105.72	105.827	105.74	105.68	106.22
S31-E13	105.41	106.00	105.55	105.34	105.49	105.76	106.03	105.92	105.92	105.86	105.86	105.64	105.50	105.32	105.19	105.13	105.30	105.66	105.717	105.51	107.59	105.50
S31-E8 (MW-8)	107.64	107.60	107.69	107.72	107.70	107.69	107.69	107.77	107.82	107.92	107.97	107.99	108.02	107.99	107.95	107.91	107.89	107.85	107.884	107.94	107.94	107.97
S32-E11 (MW-19)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	107.01	106.89	106.71	106.61	106.51	106.59	106.695	106.73	106.69	106.70
S32-E13B	107.15	106.08	105.75	105.46	105.59	105.84	106.12	106.08	106.06	106.06	106.06	105.83	105.70	105.52	105.41	105.27	105.55	105.88	105.879	105.71	105.65	105.73
S32-E8 (MW-9)	NA	NA	109.44	109.40	109.39	109.39	109.39	109.44	109.49	109.59	109.63	109.66	109.76	109.83	109.73	109.59	109.67	109.67	108.786	109.75	109.75	109.80
S34-E10 (MW-2)	107.55	107.43	107.70	107.39	107.31	107.46	107.64	107.95	108.02	108.16	108.18	107.78	108.03	107.81	107.65	107.55	107.51	107.58	107.643	107.66	107.66	107.70
S36-E12B	107.13	107.39	107.56	106.46	106.93	108.02	105.21	108.28	108.30	108.50	108.27	107.80	107.30	106.79	106.81	106.76	106.92	107.21	107.089	107.14	106.95	107.33
S36-E13A	107.07	107.38	107.51	106.41	106.92	107.96	108.18	108.18	108.36	108.38	108.16	107.70	107.22	106.74	106.78	106.70	106.87	107.18	107.098	107.14	106.96	107.29
S36-E13B	107.15	NA	NA	NA	NA	NA	NA	NA	108.37	NA	NA	NA	107.37	106.81	106.79	106.88	106.93	107.77	107.076	107.09	106.96	107.27
S37-E11 (MW-6)	107.32	107.42	107.71	106.74	106.99	107.98	108.27	108.40	108.53	108.60	108.40	107.99	107.61	107.11	109.43	106.99	107.11	107.31	107.265	107.29	107.15	107.45
S37-E12 (MW-18)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	107.38	NA	106.94	NA	107.04	107.30	NA	107.34	107.09	107.43
S37-E14	107.04	107.41	107.17	106.41	106.98	108.18	108.34	108.31	108.49	108.48	108.18	107.61	107.09	106.55	106.74	106.72	106.83	107.11	107.009	107.08	106.90	NA
S38-E11 (MW-7)	107.60	107.56	107.89	107.20	107.27	107.90	108.20	108.45	108.52	108.69	108.54	108.26	107.97	107.61	107.48	107.40	107.46	107.57	107.585	107.57	107.50	107.69
S38-E12A (MW-4)	107.26	107.56	107.68	106.61	107.10	108.30	108.48	108.52	108.63	108.68	108.40	107.89	107.38	106.89	106.97	106.93	107.04	107.32	107.226	107.28	107.11	107.45
S38-E12B (MW-5)	107.26	107.56	107.68	106.61	107.10	108.30	108.48	108.53	108.69	108.69	108.40	107.89	107.39	106.90	106.97	106.92	107.04	107.31	107.232	107.28	107.11	107.46
S40-E14	107.34	0.00	108.02	106.52	107.59	109.08	109.25	109.17	109.44	109.15	108.59	107.96	107.15	106.88	107.12	107.05	107.33	107.54	107.415	107.44	107.36	107.73
S41-E11 (MW-1)	107.84	107.63	107.88	107.56	107.54	107.86	108.05	108.28	108.45	108.59	108.53	108.35	108.20	107.95	107.81	107.73	107.72	107.73	107.72	107.70	107.67	107.83
S41-E12 (MW-3)	NA	107.42	107.73	107.05	NA	107.78	107.95	108.23	108.31	108.48	108.35	108.04	107.65	107.35	107.57	107.53	107.52	107.61	107.585	107.57	107.51	107.68
S41-E13A	107.43	107.84	107.88	106.77	107.38	108.68	108.77	108.87	109.07	108.97	108.73	108.09	107.56	107.02	107.16	107.11	107.22	107.51	107.406	107.47	107.31	107.65
S41-E13B	107.43	107.85	107.88	106.76	107.38	108.69	108.79	108.88	109.16	108.98	108.60	108.08	107.51	107.01	107.15	107.10	107.21	107.52	107.406	107.46	107.31	107.65
S41-E13C (MW-17)	107.73	NA	NA	106.76	107.40	108.54	108.94	108.74	108.94	108.83	108.51	108.04	107.45	106.96	107.16	107.09	107.18	107.46	107.348	107.39	107.31	107.60
S43-E12	107.73	107.58	107.83	107.48	107.45	107.73	107.91	108.14	108.25	108.47	108.40	107.60	108.10	107.84	107.72	107.62	107.59	107.60	107.595	107.59	107.56	107.62
MW-7A	NA	NA	NA	NA	NA								106.05		106.02	106.00						
MW-8A	NA	NA	NA	NA	NA									104.99	104.96	104.85						

BLANK – Measurements have been obtained but not yet entered into HEIS
NA – Measurements are not recorded in HEIS database

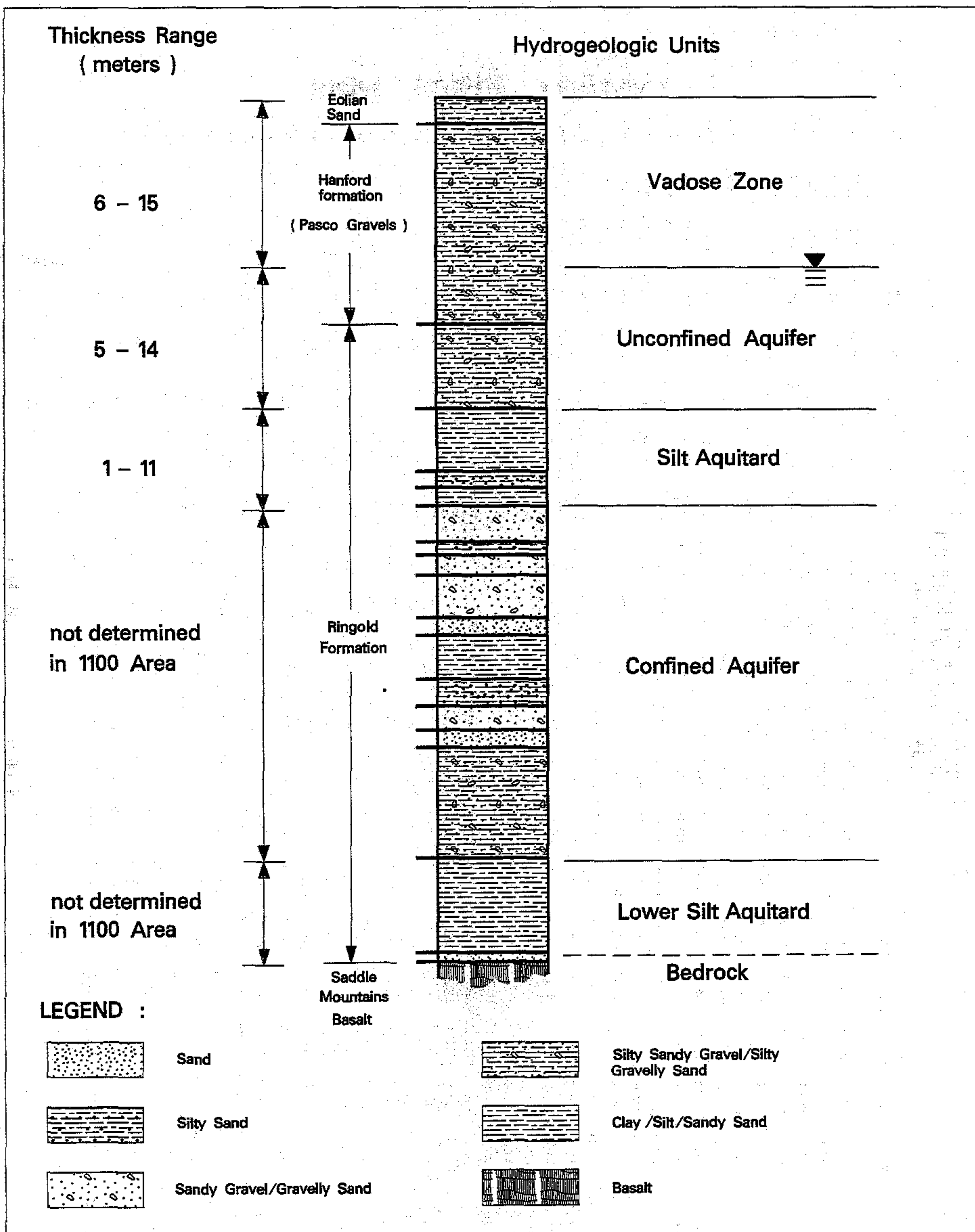


Figure 2-9. Generalized Hydrostratigraphic Column for the 1100-EM-1 Operable Unit

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Below the 1100-EM-1 Operable Unit, the thinnest portion of the vadose zone occurs on the west side of HRL, where it is only 6 m (20 ft) to the water table (see figure 2-5). East and south of the landfill, the vadose zone thickness gradually increases by 6 to 8 m (20 to 25 ft). Below the 1100-2 and 1100-3 subunits, it is about 15 m (50 ft) to groundwater, and about 14 to 15 m (45 to 50 ft) to groundwater below subunits 1100-1, 1100-4, UN-1100-6, and the Ephemeral Pool.

Hydraulic testing and surface mapping to evaluate vadose zone recharge to groundwater was not conducted during the 1100-EM-1 RI. The Hanford Site Performance Assessment (HSPA) project; however, has collected data at several locations on drainage and moisture in the vadose zone (Rockhold *et al.*, 1990). Two of these locations are within 16 km (10 mi) of the 1100-EM-1 Operable Unit. The information from these locations can be generally applied to the vadose zone underlying the Operable Unit.

The two HSPA sites located nearest to the 1100-EM-1 Operable Unit are the Buried Waste Test Facility (BWTF) Site and the Grass Site (Rockhold *et al.*, 1990). They are located about 16 km (10 mi) and 8 km (5 mi) north of the Operable Unit, respectively. The sites are instrumented to monitor in-situ water content of the sediments and cumulative drainage volumes. At the BWTF Site, lysimeters and caissons were installed using locally derived, repacked sieved sediments passing a 1.3 cm (0.5 in) mesh with about 3-percent silt and clay. At the Grass Site, neutron probe access tubes were installed in undisturbed sediments consisting of 74 percent sand, 21 percent silt, and about 5 percent clay. These sediments are similar to those occurring in the vadose zone of the 1100-EM-1 Operable Unit, but are lacking in the very coarse fraction which includes large gravel, cobbles, and small boulders.

Water-balance calculations, completed for the period from 1985 to 1989, have provided cumulative drainage volumes for the BWTF Site. The calculations were performed on data collected from two weighing lysimeters (north and south) and a caisson. Cumulative drainage volumes over the 4-year (yr) study ranged from 0.0 to 10.6 cm (0.0 to 4.5 in) for the vegetated south weighing lysimeter, 3.1 to 10.0 cm (1.3 to 4.0 in) at the unvegetated north weighing lysimeter, and 4.0 to 11.1 cm (1.7 to 4.5 in) at the unvegetated south caisson, which is deeper than either the north or south weighing lysimeters (Rockhold *et al.*, 1990). The south caisson extends to a depth of 7.6 m (25 ft), whereas the north and south weighing lysimeters extend to only 1.5 m (4 ft) below ground surface.

In general, the vegetated south weighing lysimeter had 3 to 6 cm (1.3 to 2.5 in) less drainage than the north weighing lysimeter and the south caisson from 1986 to 1989. The drainage rate in the south caisson was also reported to be more regular due to its greater depth, as compared to both the north and south weighing lysimeters, which were observed to show seasonal fluctuations (Rockhold *et al.*, 1990).

Fewer data are available to evaluate drainage from the Grass Site. A computed recharge rate for the Grass Site, based on the unit gradient principle and the average field-measured saturated hydraulic conductivity, was estimated at 0.44 cm/yr (0.17 in/yr) (Rockhold *et al.*, 1990). The unit gradient was generally observed in the field moisture content data. The smaller recharge rate at the Grass Site was attributed to the finer-grained vegetated sediments.

Computer modeling of the water table aquifer recharge rate from surface infiltration was performed during the Phase II investigation. A discussion of the modeling is provided in paragraph 6.3 of this report. Groundwater recharge within the 1100-EM-1 Operable Unit, as determined through the modeling effort, was computed as averaging 1.04 cm/yr (0.41 in/yr) for vegetated areas and 3.46 cm/yr (1.36 in/yr) for unvegetated areas. Both values are well within the ranges measured by field investigations described above.

2.4.3.1.1 Vadose Zone Properties--Soil grain-size distribution and moisture content were the only two physical properties determined for vadose zone sediments during the 1100-EM-1 Operable Unit Phase I investigation. Only soil moisture content was measured during the Phase II investigation. A detailed summary and discussion of vadose zone parameters are presented in paragraph 6.1. Tables presented there provide a compilation of the soil samples obtained for physical analyses, the borehole/well from which the samples were obtained, the depths of the samples, a summary of their grain-size composition, the measured soil-moisture contents, and the Wentworth Classification of the soil based on laboratory gradation analysis results.

Gradation percentages and classifications presented in these tables may differ from field data entered on the boring logs. Field data was based entirely on visual estimation of soil grain size and composition and, therefore, subject to the classifier's judgement. Based on the arithmetic averaging of 168 test results, the overall soil gradation within the vadose zone consists of 50-percent gravel sized particles, 42-percent sand, and 8-percent silt-sized or finer grains. Soil moisture averages 0.06 cm^3/cm^3.

2.4.3.2 Unconfined Aquifer. The unconfined aquifer below the 1100-EM-1 Operable Unit occurs between the water table and the underlying silt aquitard, approximately 95 to 107 m (310 to 350 ft) above mean sea level (amsl). The aquifer occurs within the lower Hanford formation and the upper portion of the middle Ringold Formation.

2.4.3.2.1 Aquifer Thickness--Below the 1100-EM-1 Operable Unit, the unconfined aquifer thickness gradually increases south from HRL to a trough, which occurs in the vicinity of the 1100-2 and 1100-3 subunits. Directly south from these two subunits, toward the 1100-1 subunit, the thickness does not appear to change. Southeast from the 1100-2 and 1100-3 subunits and east from the 1100-1 subunit, the thickness decreases slightly. The maximum thickness observed is 13 m (44 ft), in the vicinity of the 1100-1, 1100-2, 1100-3, and UN-1100-6 subunits. The minimum observed thickness is 5 m (16 ft) and occurs on the west side of HRL.

Outside of the 1100-EM-1 Operable Unit, fewer data are available to map the unconfined aquifer thickness. In general, the thickness appears to increase toward the Columbia River.

2.4.3.2.2 Recharge--Groundwater recharge to the unconfined aquifer below the 1100-EM-1 Operable Unit is primarily from the Yakima River located several miles west and southwest of the site. The river appears to discharge directly to the unconfined aquifer along the Horn Rapids Reach below Horn Rapids Dam (Freshley *et al.*, 1989). Irrigation losses, precipitation infiltration, and, potentially, unconfined aquifer flow beneath the Yakima River provide additional recharge to the 1100 Area groundwater. A reasonable estimate of total recharge could not be made because of the complexity of the Yakima River-unconfined aquifer interface.

Within the boundaries of the 1100-EM-1 Operable Unit, groundwater recharge also may occur as a result of natural precipitation. Based on the information presented in section 6, the volume of recharge from infiltrating precipitation is approximately between 40 and 10 times less than the westward groundwater inflow volume.

To the east of the 1100-EM-1 Operable Unit, the North Richland well field artificially recharges the unconfined aquifer to provide treatment of turbid Columbia River water and enhance the well field capacity (see figure 1-2 for well field location). This is a major source of recharge to the aquifer and causes groundwater mounding that extends west to the vicinity of the 1100-1, 1100-4, UN-1100-6, and Ephemeral Pool subunits. However, because the well field is recharged intermittently, the mound may dissipate between periods of recharge. Monthly totals for recharge at the well field during 1988 and 1989 ranged from about 75,000,000 L (20,000,000 gal) to 1,500,000,000 L (400,000,000 gal).

2.4.3.2.3 Water Table Surface Fluctuations--Groundwater surface fluctuations near the 1100 Area occur due to Columbia River stage fluctuations and variable recharge at the North Richland well field. Of the observed data sets, the June and September 1990 water surfaces (shown in figures B-1 and B-17) have, respectively, the highest and lowest surfaces due to river fluctuations. The extent of the influence of the fluctuating river boundary is seen by comparing the groundwater surfaces shown in appendix B. Comparing the June and September 1990 data sets, the influence of the major (seasonal) river stage fluctuations in the northern part of the area extends inland to about the down-gradient boundary of the HRL. The effects from the North Richland well field, and the lack of groundwater surface data, preclude identification of the extent of river influence in the southern part of the area.

As noted, recharge from the North Richland well field causes groundwater mounding in the southern part of the area as shown on the groundwater level maps. Of the observed data sets, the greatest and least amount of mounding occurred in August 1991 (figure B-9) and March 1991 (figure B-4), respectively. In the SPC/HRL area, the maximum observed northward extent of the recharge influence was to the area approximately 1,500 m south of Horn Rapids Road. The recharge mounding has not been observed to have a significant effect on groundwater levels or gradient directions within the SPC/HRL area. Well field recharge data from 1983 to the present indicates reasonably consistent yearly recharge volumes and mode of operation (*Ground-water Modeling Investigation of North Richland Well Field and the 1100 Area*, PNL Letter Report, M.D. Freshley, March, 1989).

2.4.3.2.4 Groundwater Flow--The groundwater flow direction was determined from groundwater potential measurements in monitoring wells within and adjacent to the 1100-EM-1 Operable Unit as reported in table 2-6 and the potentiometric surface maps discussed in paragraph 2.4.2.

The potentiometric surface maps indicate consistent northeasterly groundwater flow in the vicinity of the HRL and that groundwater passing through the SPC area flows to the HRL. HRL wells containing the highest concentrations of contaminants (paragraph 4.8.2) are directly down-gradient from the SPC facility. No evidence was found that would allow for groundwater flow from the SPC/HRL area to the North Richland well field. In 1952, extended pumping without recharge resulted in a local cone of depression at the well field (see map in appendix B). This pumping, without recharge, did not result in flow from the SPC/HRL area to the well field. In fact, the influence from this historical worst case extended only about one-third of the distance between the two locations.

The potentiometric maps also confirm the Phase I RI observation that local groundwater flow originating north of wells MW-7 and MW-5 (DOE/RL-90-18) does not flow to the North Richland well field. Based on these observations, there is no indication that the unconfined aquifer groundwater contamination originating at the SPC/HRL area could flow directly to the North Richland well field.

The maps also show that groundwater passing beneath the southern portion of the 1100-EM-1 Operable Unit flows eastward toward the North Richland well field when it is not obstructed by recharge mounding, and westward when mounding occurs. Examination of the 29 months of available data revealed that, for 13 months, flow was from the 1100-EM-1 eastward towards the well fields while, for 16 months, flow was reversed due to well recharge mounding. The average local surface gradients were approximately equivalent for those two conditions. Therefore, for the localized area west of the well field, the 1990 to 1992 data indicates that the recharged water dominates the direction of flow, that flow is towards the west more than towards the east, and that, if the observed recharge pattern is continued indefinitely, the natural groundwater beneath the southern portion of the 1100-EM-1 Operable Unit will not flow into the North Richland well field.

2.4.3.2.5 Discharge--Groundwater discharge from the unconfined aquifer occurs primarily into the Columbia River and to wells in the North Richland well field, depending on well field operations. Hydraulic connection between the aquifer and the river is shown by the continuity of the formation materials toward the river, and the similarity between river stage and the observed groundwater potential in the unconfined aquifer near the river.

This hydraulic connection was further demonstrated by the response of many monitoring wells to a 0.3-m (1-ft) decline in Columbia River stage from March 2 to 5, 1990. During this period, groundwater potential measured in monitoring wells nearest the river also declined approximately 0.3 m (1 ft).

2.4.3.2.6 Hydraulic Properties--Hydraulic properties for the unconfined aquifer were determined from previous investigations at this and nearby sites, and from recent pump tests performed at the SPC facility, and at a location west of Stevens Drive near the 300-FF-5 Operable Unit. Pump tests were not performed at the HRL because of concerns expressed by regulators regarding the pumping of potentially contaminated groundwater to the surface. The SPC pump test was performed close to the area of immediate concern and mainly evaluated properties of the Hanford formation. The two 300-FF-5 Operable Unit tests, at wells 7T and 4T, were located about 1/2 and 1 mile from the HRL boundary, respectively, and reflect properties of the middle Ringold Formation (figure 2-6).

Pump test results were used as the representative data for site hydraulic conductivity instead of the slug tests results reported in the Phase I RI report. This was determined after review of other hydraulic property investigations (see appendix B), discussions with the U.S. Geological Survey (USGS) concerning unpublished hydraulic property testing in the vicinity (personal communication between M. Johansen, U.S. Army Corps of Engineers, and Ward Staubitz, USGS), and the conventional understanding that pump test results are more representative than slug test data because a larger area of the aquifer is stressed. There were also concerns reported in the Phase I RI and in the 300-FF-5 aquifer test report about the accuracy of the slug test results for wells with small screen mesh sizes (10 to 20 slot at the 1100 Area and 30 slot at the 300-FF-5 Area) and accompanying screen packing material.

The SPC pump test was conducted April 27 through 30, 1992, by pumping well TW-1 (located near SPC monitoring well GM-5 as shown in figure 6-13) at approximately 154 gallons per minute (gpm) for a period of 72 hours; a time period sufficient for test stabilization (see appendix F). The pumping rate was determined from a previously performed step-drawdown test. The driller's log for well PW-1 shows the base of the screen to be located a few feet above the silt aquitard layer with the screen extending 15 feet upward to the vicinity of the water table. The contact between the Hanford and Ringold Formations is interpreted as occurring approximately at the midpoint of the screened interval with slightly more length screened in the Pasco gravels of the Hanford formation. The pump test largely evaluated the properties of the Hanford formation since most of the pumped water was likely derived from the more permeable Pasco gravels. Based on test results, the estimated transmissivity of the unconfined aquifer in the vicinity of the pumping well was approximately 2,460 to 3,140 m^3/d-m (180,000 to 230,000 gallons per day per foot). Corresponding horizontal hydraulic conductivities range from 400 to 520 meters per day (m/d) (1,320 to 1,700 feet per day [ft/d]). The information is preliminary and is to be finalized and presented in an RI report for SPC scheduled for release in the spring of 1993.

Aquifer testing at the 300-FF-5 sites was conducted from January to May of 1992 in 10-inch-diameter wells equipped with 30-slot, wire-wrap screens (WHC, 1992c). The two test wells were screened entirely within the middle Ringold Formation with screen lengths for wells 4T and 7T being 20.2 and 30.5 feet, respectively. Three observation wells were constructed for each test well and several different slug and pump tests were performed. The slug test results were reported as unrepresentative of aquifer properties because of the effects of the fine filter pack material required by the 30-slot size screens. The pump test results were horizontal conductivities of 10 - 72 m/d (33 to 236 ft/d) vertical conductivities of 2 to 5 m/d (6.6 to 16 ft/d), and a storage coefficient of 0.01 - 0.58 (S_y). The constant discharge tests (Neuman analysis) were reported to provide the best estimate of the unconfined aquifer properties with results of 37 to 49 m/d (121 to 161 ft/d) (K_h), 2 to 5 m/d (6.6 to 16 ft/d) (K_v), and 0.02 - 0.37 (S_y).

The SPC and 300-FF-5 pump tests reviewed provided the best estimates of aquifer properties in the HRL vicinity. However, additional information concerning the hydraulic properties of the unconfined aquifer near the river was for use in groundwater modeling.

The water table contour maps (appendix B) show that the groundwater surface near the 300 Area is consistently and distinctly flatter than the up-gradient surface near the HRL. According to the governing principles of groundwater flow, this decrease in the slope is consistent with the presence of relatively high aquifer hydraulic conductivities in this area. The upgradient pump tests results were, therefore, not extrapolated into this area. The best available hydraulic property information for this area were K_h measurements of 3,350 - 15,000 m/d (10,991 to 49,215 ft/d) for the local Hanford formation [RI/FS Work Plan for the 300-FF-5 Operable Unit, Hanford Site, Richland, Washington (DOE/RL-89-14)].

An earlier pumping test completed at the North Richland well field provided a single hydraulic conductivity estimate of 457 m/d (1E+03 ft/d), which is more typical for the unconfined aquifer. At the well field, the unconfined aquifer occurs within both the Hanford formation and middle Ringold Formation. During this test, water was withdrawn from the aquifer at a rate of 5,070 l/min (1,340 gal/min). Although the test continued for a total of 98 hours, all observed drawdown occurred in the first 24 hours. A total drawdown of 1.2 m (4 ft) was measured in the pumping well. In an observation well 107 m (350 ft) away, the total drawdown was only 0.20 m (0.66 ft). These results are consistent with those of the SPC test.

Estimating site groundwater velocities, particularly those between the SPC lagoon area and the wells near the down-gradient boundary of the HRL (*e.g.*, MW-12 area), required estimating the average hydraulic conductivities between these areas. Using exclusively either of the conductivity estimates from the two pump tests, referred to above, to calculate site velocities would have been inappropriate since the aquifer is dominated by Hanford material near SPC and the Ringold Formation near MW-12. It was recognized that some mixing of the Hanford and Ringold deposits likely occurred and that the contact line between the two is not exactly defined. Given this, an estimate of the average hydraulic conductivity between the SPC lagoons and well MW-12 was derived by assuming that the conductivities at the MW-12 area were similar to those from the 300-FF-5 (both in Ringold Formation). The upper and lower bounds of the pump tests were then averaged, resulting in an estimated range of about 200 to 300 m/d (656 to 984 ft/d) for the average conductivity between the SPC lagoons and the MW-12 area.

Using the above hydraulic conductivity range, an average pressure gradient of 0.0022 m/m from observed groundwater levels and a porosity of 0.30 yields flux velocity and average linear (pore) velocity estimates of 0.44 to 0.66 m/d and 1.46 to 2.20 m/d, respectively, between the SPC lagoon and MW-12 areas.

Table 2-7 summarizes the estimated hydraulic properties for the hydrogeologic units at the site. Those values not taken from the information reported above, were estimates and observations taken from DOE/RL-90-18 and other investigations at Hanford as reported in appendix B. Where no previous site-specific data was available, the estimated value, or range, was extrapolated from the nearest available measured value (*i.e.*, some vertical hydraulic conductivity estimates were derived from measured horizontal conductivity values by using a 1 to 10 ratio).

2.4.3.3 Silt Aquitard. A silt aquitard was identified during drilling throughout the 1100-EM-1 Operable Unit, and is also recognized in the drill logs of previous workers in the general vicinity (see appendix C for further details and maps defining stratigraphic characteristics, thicknesses, and areal extent of the silt aquitard). The aquitard was encountered within the interval from 91 to 102 m (299 to 333 ft) amsl. Wells drilled to elevations lower than 91 m (299 ft) amsl invariably intercepted the aquitard. There is, however, uncertainty regarding the continuity of this layer. A possibility exists for the aquitard to be discontinuous due to erosion that may have occurred before the overlying sediments were deposited.

2.4.3.3.1 Aquitard Thickness and Extent--The reported thickness of the silt aquitard ranges from 1.04 to 10.1 m (3.4 to 33 ft) (see table C-1). A thickness of only 1.04 m (3.4 ft) was observed in MW-21. At this location, the unit is overlain by a 7.04 m (23.1 ft) thick volcanic ash layer (see appendix C). The ash appears to have been alluvially deposited in an isolated depression on the top of the silt. On the west side of HRL, at MW-9, the silt aquitard thickness is measured to be 10.1 m (33 ft). A short distance west of the North Richland well field, in MW-17, the aquitard is 5.5 m (18 ft) thick. Within the North Richland well field, wells 10/28-23P01 and 10/28-26C01 appear to extend through the silt aquitard. However, the locations of these wells could not be confirmed in the field. Several other logs indicate a silt or clay interval being intercepted at the bottom of the borehole.

The change in thickness of the aquitard is interpreted to reflect undulations in its upper surface. This surface likely was subject to erosion based on the high-energy sand and gravel deposits that overlie it and the apparent geometry of the ash deposit previously described. The lower surface of the silt appears to be relatively flat (based on six data points), varying in elevation by less than 3 m (10 ft) over a 6 km (3 mi) north-south transect passing through the 1100-EM-1 Operable Unit (see cross section A-A", figure 2-4).

The uniformity and gradation in elevation of the lower surface of the silt, as observed, suggests the aquitard may be a continuous stratum; however, the undulating upper surface indicates the potential for complete erosion of the silt in localized areas. Below the 300 Area, a silt aquitard, which occurs at about the same elevation as that below the 1100-EM-1 Operable Unit, pinches out near the Columbia River channel, an indication of complete erosion in this area (see figure C-2). However, it is not clear that these two silt horizons are absolutely correlative.

The Ringold silt layer present within the 1100-EM-1 Operable Unit is, at least partially, discontinuous to the east, adjacent to the Columbia River. This is evident in the head differences obtained from two well clusters (MW-8 and 9 located along the western edge of HRL and wells 7A, 7B, and 7C located within the 300-FF-5 Operable Unit), which indicated upward pressure head differences of 2.0 and 0.3 m (6.6 and 1.0 ft), respectively.

MW-21, which penetrates the confined aquifer at the eastern edge of HRL, presents an anomaly to this trend. Water level measurements indicate that a slightly lower potentiometric surface exists in the confined aquifer versus the unconfined aquifer at this location. Water level elevation differences average 0.13 m (0.43 ft) with a maximum difference of 0.18 m (0.59 ft) and a minimum of 0.10 m (0.33 ft); the water level elevation in the lower confined aquifer being lower than that in the upper unconfined aquifer. A preliminary check of the top-of-casing elevation listed for well MW-21 suggests the anomaly may be partly the result of survey error. Alternately, the well seal may be compromised, which could also account for a portion of the observed anomaly. An elevation survey of 1100 Area wells is underway. This anomaly will be re-evaluated when the new survey data becomes available.

2.4.3.3.2 Hydraulic Properties--Ten samples of the silt aquitard were used to measure the vertical hydraulic conductivity of this confining layer. The hydraulic conductivity results ranged from 2.5E-05 to 4.3E-02 m/d (8E-04 to 1E-01 ft/d) (DOE/RL-90-18). These values were several orders of magnitude lower than in the overlying unconfined aquifer. The laboratory test results may not, however, be representative of the true hydraulic conductivities of the sediments due to sampling disturbances.

The confining ability of the aquitard is shown by comparison of the groundwater potentials in monitoring wells MW-8 and MW-9 on the west side of HRL. MW-9 is screened entirely within sediments underlying the silt aquitard and has groundwater potentials approximately 1.9 m (6.3 ft) greater than those in MW-8, which is screened above the aquitard. Under these conditions, an upward hydraulic gradient across the aquitard exists.

At MW-17, the groundwater potential difference across the aquitard was essentially zero. The absence of a potential gradient at MW-17 may be attributed to the occurrence of a window through the aquitard, mounding effects caused by recharge at the well field, a change in the depositional or diagenetic facies of the aquitard, or poor well construction. In general, an easterly decline in the hydraulic gradient across the aquitard is anticipated, as the aquitard likely pinches out in this direction, thereby allowing the unconfined aquifer to equilibrate with the aquifer below.

2.4.3.4 Confined Aquifer. The upper confined aquifer occurs immediately below the silt aquitard. Information on this aquifer is limited, as the 1100-EM-1 RI hydrogeological investigation focused primarily on the vadose zone and unconfined aquifer.

The upper confined aquifer is monitored by wells MW-9, MW-17, and MW-21. The groundwater potentials measured in these wells indicate that flow is apparently toward the east. There is also flow upward into the silt aquitard that occurs above the confined aquifer, with the possible exception of MW-21 as discussed in paragraph 2.4.3.3.1. It is presently unknown if North Richland well field operations have significant affects on the flow observed in this aquifer, although minor fluctuations observed in water levels measured in well MW-17 indicate that at least some minor effect is likely.

The sediments encountered in the confined aquifer ranged from silty sand to sandy gravel of the middle Ringold Formation. Rising head slug tests conducted in MW-9 and MW-17 yielded hydraulic conductivity estimates of .34E-01 m/d (1.0 ft/d) and 0.086 m/d (0.30 ft/d), respectively, indicating that at least in these two locations the hydraulic conductivity is generally lower than in the unconfined aquifer.

The horizontal and vertical extent of the upper confined aquifer is not well defined. Lindberg and Bond (1979) show the upper confined aquifer merges with the unconfined aquifer near the Columbia River within the 300 Area, and Newcomb *et. al.*, (1972) report on a well drilled through the upper confined aquifer southwest of the 300 Area. During drilling for the initial phase of the 1100-EM-1 RI, the upper confined aquifer was identified at HRL at MW-9, and to the south at MW-6 and MW-17. The vertical thickness of the upper confined aquifer may vary from a few meters up to 10 m (30 ft), depending on the continuity of silt strata in the middle Ringold unit. During the RI, no explorations penetrated the full thickness of the upper confined aquifer below the 1100-EM-1 Operable Unit.

2.4.3.5 Lower Silt Aquitard. A clayey silt to silty clay unit is assumed to overlie the bedrock surface below the 1100-EM-1 Operable Unit except where separated by a thin sand unit. There are no wells within the Operable Unit that extend deep enough to confirm this assumption. Well log data in the 300 Area show that the aquitard is separated from bedrock by a thin sand that is likely irregular and discontinuous. Based on remote well data, it is assumed that the lower silt aquitard, in places, may not be in direct contact with bedrock below the Operable Unit (DOE/RL-89-14).

This fine-grained unit serves as the major aquitard separating water-bearing units in the basalt bedrock from water-bearing strata of the suprabasalt sedimentary sequence. In the 1100-EM-1 groundwater model, the lower silt aquitard is assigned the role of lower bounding unit for the geometric block of sediments of which the model is composed.

Table 2-7. Measured and Estimated Saturated Zone Hydraulic Properties

Hydrogeologic Unit	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Storage Coefficient	Porosity (effective)
Unconfined Aquifer				
Hanford Formation (near HRL)	400 - 520	40 - 50*	.02 - .37*	.20 - .33*
Hanford Formation (near 300 Area)	3350 - 15000	330 - 1500*	.02 - .37*	.20 - .33*
Ringold Formation	10 - 72	2 - 5	.02 - .37	.11 - .30*
Silt Aquitard	.001 - .03	.0001 - .003*		.20 - .33*
Confined Aquifer	10 - 72	2 - 5		.11 - .30*

* Value, or range, is based on general reported values at the Hanford site (appendixes B and F) or extrapolated from nearest available value.

3.0 SITE INVESTIGATIONS

Investigations completed for the 1100-EM-1 Operable Unit RI will be summarized in the following sections. Subunits will be discussed in the sequence: 1100-1, Battery Acid Pit; 1100-2, Paint and Solvent Pit; 1100-3, Antifreeze and Degreaser Pit; 1100-4, Antifreeze Tank Site; UN-1100-6, Discolored Soil Site; Ephemeral Pool; and, HRL. Subunits UN-1100-5, Radiation Contaminant Incident; Pit No. 1; and, the Hanford Patrol Academy Demolition Site were eliminated from further consideration for remediation during the Phase I portion of the RI (DOE/RL-90-18). Of these three sites eliminated, the first two were deleted from further consideration due to a lack of substantive contamination detected at the sites. It is anticipated that the Hanford Patrol Academy Demolition Site will be addressed separately, if necessary, under Ecology's RCRA authority.

The discussion of site investigations will begin with a general description of each subunit. Following the site description, details of individual investigations completed at each subunit will be presented including soil sampling and analysis, soil-gas sampling efforts, and geophysical investigations. Then, a summary of all subunit soil investigations, and screened contaminants will be presented. Finally, groundwater investigations will be discussed on an Operable Unit-wide basis in the last paragraph of this section.

Soil [0 to 0.7 m (0 to 2.0 ft)] contaminants detected within the 1100-EM-1 Operable Unit are presented in table 3-1. Subsurface [> 0.7 m (2 ft)] contaminants detected at the 1100-EM-1 Operable Unit are presented in table 3-2. Table entries highlight those substances detected in concentrations above Upper Tolerance Limits (UTL) (see appendix K). The UTL is used as the project-specific background level and contaminants are defined as those analytes detected at concentrations above UTL. The UTL values were taken from Phase I Report DOE/RL-90-18. The background locations, size of sample set are described in DOE/RL-90-18. The background conditions were characterized by means of the one-sided UTL of the 95th percentile ($\alpha = 0.05$) for the distribution of each parameter. Further explanation and the method for the UTL calculations is provided in both chapter III of appendix K and DOE/RL-90-18. Phase I analytical parameters for soils consisted of EPA TAL and TCL parameters (EPA, 1989a and 1989b, respectively). Phase II analytical parameters were more restrictive in that Phase II analyses focused on contaminants of potential concern identified during the Phase I investigation (DOE, 1990).

Surface radiation surveys were conducted at all 1100-EM-1 Operable Unit subunits. All radiation surveys were negative. These will not be considered further.

3.1 BATTERY ACID PIT-1100-1

The Battery Acid Pit was an unlined, sand filled sump/french drain excavated in native soil deposits approximately 30 m (100 ft) from the southwest corner of the 1171 Building (figure 3-1) . During the period between 1954 to 1977, an estimated volume of 57,000 l (15,000 gal) of waste battery acid from vehicle maintenance activities was deposited in the pit. Information gathered through interviews with former site workers suggest that other substances including waste oil, waste antifreeze, and spent solvents were

Table 3-1 Maximum Concentrations for Detected Compounds, Compared to UTL's for Surface Soils (0 to 2 Feet) from Phase I and II Data (Sheet 1 of 4)

Parameter	Surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
INORGANIC COMPOUNDS (mg/kg)								
Aluminum	9708.79	7130	8300	**9770**	7320	8680	**15800**[b]	5810
Antimony	3.70	ND	ND	ND	ND	ND	**15.6**[b]	ND
Arsenic	3.99	3.2	2.3	3.4	2.6	2.7	3.6	2.6
Barium	120.10	80.8	91.5	106	80.9	99.2	**1320**	72.3
Beryllium	0.74	ND	0.51	0.44	0.25	0.4	**1.3**	0.26
Cadmium	0.70	ND	ND	ND	ND	ND	**2**	ND
Calcium	5129.25	**8690**	**6480**	**6810**	**9710**	4180	**86700**	3030
Chromium	12.94	10.6	**16.8**	14	11.3	10.9	**17.1**	7.7
Cobalt	17.74	13.2	13.9	14.1	11.4	12.2	15.9[b]	10.3
Copper	19.11	**37.9**	**24.4**	**22.8**	14.4	16.2	**58.6**	15.2
Iron	31110.42	21100	26600	25500	23300	23500	29800	18900
Lead	12.64	**266**	**94.6**	**26.4**	5	**22.1**	**482**	**54.2**
Magnesium	6523.59	6430	5210	6170	4650	4840	**25000**	4250
Manganese	552.27	464	365	436	330	383	423	354
Mercury	0.10	**0.22**	ND	ND	ND	ND	**1.3**	ND
Nickel	19.00	**20.9**	15	14.9	9.8	12.9	**174**	12.5
Potassium	1909.71	850	**2060**	1730	1210	**1950**	**2230**	1140
Selenium	0.39	ND	ND	ND	ND	ND	**0.97**[b]	ND
Silver	2.44	ND	ND	ND	ND	ND	**4.5**	ND
Sodium	241.52	**479**	**374**	**495**	**413**	143	**5140**[b]	216
Thallium	0.39	ND	**0.48**	**.40**	ND	ND	**.42**	ND
Vanadium	83.93	32.5	73.4	70.2	61.8	60.8	**87.3**	44.4
Zinc	62.20	**92**	56.6	59	45.9	**111**	**408**	**67.5**
Cyanide	0.52	ND	ND	ND	ND	ND	**0.56**	ND

Table 3-1 Maximum Concentrations for Detected Compounds, Compared to UTL's for Surface Soils (0 to 2 Feet) from Phase I and II Data (Sheet 2 of 4)

Parameter	Surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
VOLATILE ORGANIC COMPOUNDS (µg/kg)								
1,1,1-trichloroethane	5	ND	2	ND	ND	**35**	ND	ND
1,1-dichloroethene	5	ND	**5**	ND	ND	ND	ND	ND
2-butanone	11	ND	10[a]	**17**[a]	ND	**69**[a]	**35**[a,b]	ND
2-hexanone	11	ND	ND	ND	ND	**53**	ND	ND
Acetone	43	ND	19[a]	**92**[a]	6[a]	**190**[a]	ND	ND
Chlorobenzene	5	ND	**6**	ND	ND	ND	ND	ND
Methylene chloride	5	ND	**42**[a]	**120**[a]	ND	**20**[a]	**43**[a]	4[a]
Tetrachloroethene	5	ND	**35**	ND	ND	ND	**5**	ND
Toluene	5	ND	**11**[a]	**6**[a]	ND	**8**[a]	**16**[a]	ND
Trichloroethene	5	ND	**6**	ND	ND	ND	ND	ND
Xylene	5	ND	**6**	ND	ND	ND	ND	ND
SEMI-VOLATILE ORGANIC COMPOUNDS (µg/kg)								
1,2,4-trichlorobenzene	690	ND	120	ND	ND	83	ND	ND
1,3-dichlorobenzene	690	ND	120	ND	ND	ND	ND	ND
1,4-dichlorobenzene	690	ND	120	ND	ND	86	ND	ND
2-chlorophenol	690	ND	230	ND	ND	170	ND	ND
2-methylnaphthalene	690	ND	ND	ND	ND	ND	**7100**	ND
2,6-dinitrotoluene	690	ND	ND	ND	ND	ND	210[b]	ND
4-chloro-3-methylphenol	690	ND	190	ND	ND	95	ND	ND
4-nitrophenol	3300	ND	ND	ND	ND	ND	**3800**	ND
Acenaphthene	690	ND	110	ND	ND	77	ND	ND
Anthracene	690	ND	ND	ND	ND	ND	70[b]	ND

Table 3-1 Maximum Concentrations for Detected Compounds, Compared to UTL's for Surface Soils (0 to 2 Feet) from Phase I and II Data (Sheet 3 of 4)

Parameter	Surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
SEMI-VOLATILE ORGANIC COMPOUNDS (μg/kg) (continued)								
Benzoic acid	2790	ND	ND	ND	ND	ND	220[a]	ND
Benzo(a)anthracene	690	ND	ND	120	ND	ND	180	ND
Benzo(a)pyrene	690	ND	110	150	ND	ND	200	ND
Benzo(b)fluoranthene	690	150	79	180	ND	ND	250	ND
Benzo(g,h,i)perylene	690	ND	330	230	ND	ND	150	ND
Benzo(k)fluoranthene	690	ND	120	160	ND	ND	190	ND
Bis(2-ethylhexyl)phthalate	690	390[a]	290[a]	940[a]	ND	**2.5E+07**	ND	ND
Butylbenzylphthalate	690	ND	ND	ND	ND	ND	99[a]	ND
Chrysene	690	100	ND	170	ND	ND	240	ND
Dibenzofuran	690	ND	ND	ND	ND	ND	130	ND
Dibenz(a,h)anthracene	690	ND	300	110	ND	ND	ND	ND
Di-n-butyl phthalate	690	ND	ND	ND	ND	ND	65[b]	ND
Di-n-octyl phthalate	690	ND	67[a]	ND	ND	**46000**	ND	ND
Fluoranthene	690	110	ND	220	ND	ND	180	ND
Indeno(1,2,3-cd)pyrene	690	ND	300	230	ND	ND	170	ND
Naphthalene	690	ND	ND	ND	ND	ND	1100	ND
N-nitroso-di-n-propylamine	690	ND	110	ND	ND	78	ND	ND
Pentachlorophenol	3300	ND	ND	99	ND	ND	980[b]	ND
Phenanthrene	690	ND	ND	130	ND	ND	380[b]	ND
Phenol	38100	ND	94	ND	ND	ND	ND	ND
Pyrene	690	97	120	250	ND	94	220	ND

Table 3-1 Maximum Concentrations for Detected Compounds, Compared to UTL's for Surface Soils (0 to 2 Feet) from Phase I and II Data (Sheet 4 of 4)

Parameter	Surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
PESTICIDES/PCB's (μg/kg)								
4,4"-DDE	33	6.8	**42**	ND	ND	**170**	**1200**	ND
4,4'-DDD	33	ND	3.6	ND	ND	ND	**260**	ND
4,4'-DDT	33	ND	**57**	ND	ND	ND	**520**[b]	ND
Aldrin	17	ND	9.6[a]	1.1[a]	ND	9.6[a]	11[b]	ND
Alpha-chlordane	170	6.5	ND	ND	ND	**1000**	**770**[b]	**1100**[b]
Total PCB's	1510	290	300	150	ND	ND	**100550**	**42000**
Aroclor 1248	170	ND	ND	ND	ND	ND	**100000**[b]	ND
Aroclor 1260	330	290	300	150	ND	ND	260	**42000**[b]
Aroclor-1254	330	ND	ND	ND	ND	ND	290	ND
Beta-BHC	17	ND	ND	ND	ND	ND	**94**[b]	ND
Delta-BHC	14	ND	ND	ND	ND	13	ND	ND
Dieldrin	33	ND	1.3	ND	ND	2.3	**1200**[b]	ND
Endosulfan II	33	ND	ND	ND	ND	ND	**110**[b]	160
Endosulfan sulfate	33	ND	ND	ND	ND	ND	19	ND
Endrin	33	ND	ND	ND	ND	ND	**280**[b]	39
Endrin ketone	33	ND	2	ND	ND	1.3	**140**[b]	ND
Gamma-BHC(Lindane)	17	ND	ND	ND	ND	0.77	1.9	ND
Gamma-chlordane	158	6.2	ND	ND	ND	**860**	82	**1700**[b]
Heptachlor	17	ND	1.2	ND	ND	**65**	ND	29
Methoxychlor	170	ND	ND	ND	ND	ND	140[b]	ND

ND - Contaminant not detected above the sample quantitation limit for the method used
UTL - Upper tolerance limit
[a]Concentration less than detection limit after blank-adjustment
[b]Phase II data

Table 3-2 Maximum Concentrations for Detected Compounds, Compared to UTL's for Subsurface Soils (> 2 Feet) from Phase I and II Data (Sheet 1 of 3)

Parameter	Sub-surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
INORGANICS (mg/kg)								
Aluminum	6236	5860	7470	7400	6680	NS	17800[b]	NS
Antimony	3.1	ND	3	ND	ND	NS	15.6[b]	NS
Arsenic	2.92	3.2	1.8	1.8	5.8	NS	6.6	NS
Barium	236	85.9	96.6	85.9	98.7	NS	511[b]	NS
Beryllium	0.27	ND	ND	ND	0.93	NS	1.1[b]	NS
Cadmium	0.36	ND	ND	ND	ND	NS	2.4[b]	NS
Calcium	7830	6240	13000	9080	10600	NS	44800[b]	NS
Chromium	47.3	14.6	10.3	13.6	13.2	NS	1250	NS
Cobalt	16.8	11.8	15.3	17.8	16.5	NS	42.5	NS
Copper	19.5	25	23.6	31.7	19.8	NS	1280[b]	NS
Cyanide	0.51	ND	ND	ND	ND	NS	0.56	NS
Iron	29400	25800	27100	31700	26700	NS	35200	NS
Lead	5	191	45.9	4.7	5.7	NS	854[b]	NS
Magnesium	4680	3860	4620	5290	4630	NS	7640[b]	NS
Manganese	355	249	366	381	329	NS	501[b]	NS
Mercury	0.1	0.39	ND	ND	ND	NS	0.44	NS
Nickel	26	9.5	13.8	11.3	10.7	NS	557	NS
Potassium	966	4880	1200	878	1030	NS	3820[b]	NS
Selenium	0.41	ND	ND	ND	ND	NS	0.36	NS
Silver	0.54	ND	ND	ND	2	NS	7.7	NS
Sodium	419	808	458	999	726	NS	2360[b]	NS
Thallium	0.41	ND	ND	ND	0.48	NS	0.46	NS
Vanadium	115	118	80.2	103	82.4	NS	101	NS
Zinc	50.4	100	54.9	60	63.8	NS	3160[b]	NS

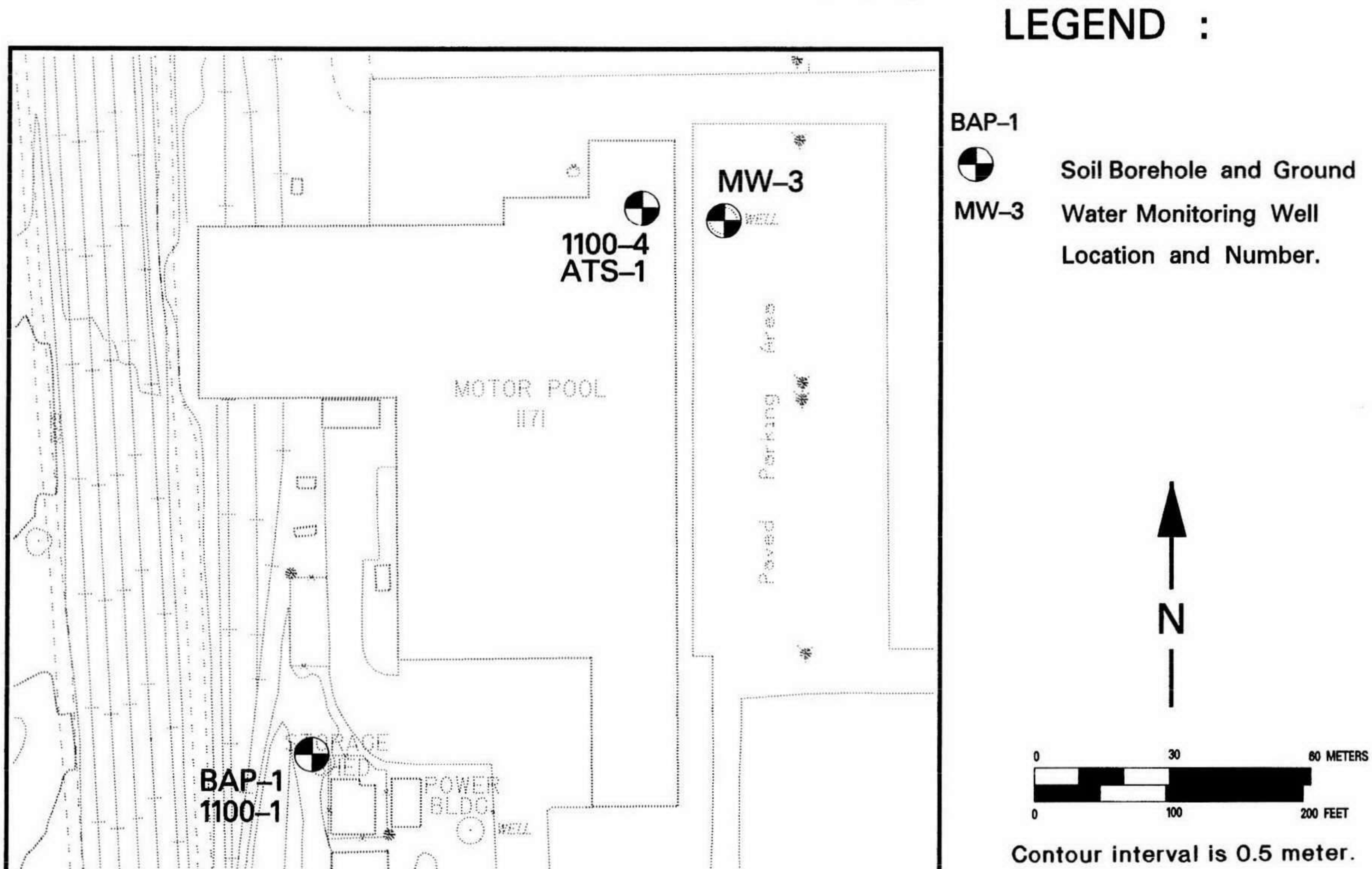
Table 3-2 Maximum Concentrations for Detected Compounds, Compared to UTL's for Subsurface Soils (> 2 Feet) from Phase I and II Data (Sheet 2 of 3)

Parameter	Sub-surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
VOLATILE ORGANIC COMPOUNDS (µg/kg)								
2-butanone	11	9[a]	8[a]	**11[a]**	ND	NS	**23[a]**	NS
Acetone	22	**26[a]**	**28[a]**	**29[a]**	9[a]	NS	**200**	NS
Benzene	5	ND	ND	ND	ND	NS	0.3[b]	NS
Ethylbenzene	5	ND	2	ND	ND	NS	ND	NS
Methylene chloride	5	ND	**61[a]**	**16[a]**	ND	NS	**5[a]**	NS
Tetrachloroethene	5	ND	**16[b]**	ND	ND	NS	4[b]	NS
Toluene	5	ND	3[a]	ND	ND	NS	ND	NS
SEMI-VOLATILE ORGANIC COMPOUNDS (µg/kg)								
1,2,4-trichlorobenzene	350	ND	ND	ND	ND	NS	230[b]	NS
1,4-dichlorobenzene	350	ND	ND	ND	ND	NS	170	NS
2-chlorophenol	350	ND	ND	ND	ND	NS	240[b]	NS
2,4-dinitrotoluene	350	ND	ND	ND	ND	NS	92	NS
4-chloro-3-methylphenol	350	ND	ND	ND	ND	NS	290	NS
4-nitrophenol	1700	ND	ND	ND	ND	NS	310	NS
Acenaphthene	350	ND	ND	ND	ND	NS	320[b]	NS
Benzoic Acid	1700	ND	ND	ND	ND	NS	160[a,b]	NS
Benzo(b)fluoranthene	350	74	ND	ND	ND	NS	ND	NS
Bis(2-ethylhexyl) phthalate	350	ND	**3600[a]**	**950[a]**	ND	NS	**1000[a]**	NS
Di-n-butylphthalate	350	ND	37	ND	ND	NS	ND	NS
Di-n-octylphthalate	350	ND	ND	ND	ND	NS	270[a,b]	NS
Fluoranthene	350	110	ND	ND	ND	NS	ND	NS
N-nitro-di-n-propylamine	350	ND	ND	ND	ND	NS	170	NS
Pentachlorophenol	1700	ND	ND	ND	ND	NS	260	NS
Phenol	350	ND	ND	ND	ND	NS	330[b]	NS
Pyrene	350	84	290	ND	ND	NS	270[b]	NS

Table 3-2 Maximum Concentrations for Detected Compounds, Compared to UTL's for Subsurface Soils (> 2 Feet) from Phase I and II Data (Sheet 3 of 3)

Parameter	Sub-surface Soil UTL	Max Value 1100-1	Max Value 1100-2	Max Value 1100-3	Max Value 1100-4	Max Value 1100-6	Max Value HRL	Max Value EP
PESTICIDES (μg/kg)								
Aldrin	17	ND	16[a]	ND	ND	NS	5.5[a,b]	NS
Alpha-chlordane	170	1.3	ND	ND	ND	NS	13[b]	NS
4,4'-DDE	34	ND	**39**	ND	ND	NS	14	NS
4,4'-DDT	34	ND	**121**	ND	ND	NS	ND	NS
Beta-BHC	17	ND	ND	ND	ND	NS	1.2[b]	NS
Dieldrin	34	ND	ND	ND	ND	NS	**90**[b]	NS
Endrin	34	ND	ND	ND	ND	NS	**120**[b]	NS
Endrin ketone	34	ND	22	ND	ND	NS	ND	NS
Heptachlor	17	ND	ND	0.58	ND	NS	ND	NS
Total PCB's	1530	ND	160	ND	ND	NS	**2640**	NS
Aroclor 1248	170	ND	ND	ND	ND	NS	**640**	NS
Aroclor 1254	340	ND	ND	ND	ND	NS	**2000**[b]	NS
Aroclor 1260	340	ND	160	ND	ND	NS	ND	NS

Notes:
ND: Contaminant not detected above the sample quantitation limit for the method used
UTL: Upper tolerance limit
NS: No subsurface samples collected for analysis
[a]Concentration less than five times the amount detected in blank and thus regarded as undetected at concentration reported (DOE/RL 90-18)
[b]Phase II data



1100-1 and 1100-4 Operable Subunits Soil Sampling Locations.

Figure 3-1

also deposited in the pit. No documentation exists to support these claims. Periodically, during the operation of this facility, the acid-laden sand lining was removed and deposited at an undetermined location and fresh sand fill installed. The pit dimensions during its use as a disposal facility are reported to have been roughly 1.8 m (6 ft) in diameter by 1.8 m (6 ft) in depth. The Battery Acid Pit is no longer visible at the site. When withdrawn from service, the pit was filled with locally derived sands and gravels and graded to match the surrounding ground surface.

3.1.1 Vadose Zone Sampling

A single borehole was advanced during the Phase I RI at the 1100-1, Battery Acid Pit subunit. This borehole yielded one sample from the surface and seven from the subsurface strata. Sampling and analysis were performed as described in DOE/RL-90-18. Inorganic contaminants were found in surface and subsurface samples. No organic contaminants were detected at this site. Contaminants identified in surface soil samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Calcium	Copper	Lead	Magnesium
Mercury	Nickel	Sodium	Zinc

<u>Organic Contaminants</u>
(None encountered)

Contaminants identified in subsurface samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Arsenic	Copper	Lead	Mercury
Potassium	Sodium	Vanadium	Zinc

<u>Organic Contaminants</u>
(None encountered)

No soil samples were collected at the 1100-1, Battery Acid Pit subunit during the Phase II RI.

3.1.2 Geophysical Investigation

A single geophysical survey was performed at the Battery Acid Pit during the Phase I investigation. Geophysical methods employed included Electromagnetic Induction (EMI), Magnetometry (MAG), Metal Detection (MD), and Ground Penetrating Radar (GPR). The geophysical investigation was conducted during the months of January through April 1989 and covered an area of approximately 390.2 square meters (4,200 square feet). Its purpose was to identify the physical location of the former waste disposal site, and to locate any underground utilities adjacent to the pit so they could be avoided during subsequent site investigations.

Survey lines were spaced at close intervals [0.76 m (2.5 ft)] because of the small size of the disposal pit [1.83 meters square (6 feet square)]. GPR signal returns were complex and difficult to interpret. As noted above, the entire site appears to have been excavated and subsequently backfilled resulting in the complex GPR returns. It was difficult to accurately locate the pit based on geophysical data because of the disturbed nature of the area. A best-guess location map was prepared based on the geophysical data and was used to site soil-gas probes installed in the next phase of the initial characterization activities. A single water supply line was identified at a depth of 1.2 m (4 ft) extending from the 1171 Building to a shower facility located immediately north of the Battery Acid Pit. Two unidentified cables or pipelines were identified to the west of the Battery Acid Pit (Sandness *et.al.*, 1989).

Geophysical surveys were not performed during the 1100-EM-1 Phase II investigations at the 1100-1, Battery Acid Pit subunit.

3.1.3 Soil-Gas Investigation

Five temporary soil-gas probes were installed at the Battery Acid Pit in June, 1989, as part of the Phase I investigation. One probe was placed in the approximate center of the Battery Acid Pit as located from measurements obtained through interviews with past area employees and by ground penetrating radar surveys. One probe was placed immediately west of the pit center, and the remaining three located along a north-south line to the east of the former disposal site. No contamination was detected during the analyses of the soil-gas samples (Evans, 1989).

Soil-gas investigations were not performed during Phase II RI of the 1100-EM-1 Operable Unit at this subunit.

3.1.4 Summary of Investigations

Site investigations at the 1100-1 subunit, Battery Acid Pit, detected inorganic contaminants in soils. Geophysical surveys detected the presence of an underground water line in the vicinity of the subunit and two questionable finds that may represent underground cables or pipelines. Soil-gas investigations failed to identify contaminants at the subunit.

3.2 PAINT AND SOLVENT PIT-1100-2

The Paint and Solvent Pit is a semicircular depression located approximately 1.6 km (1 mile) north of the 1171 Building (figure 3-2). Originally a sand and gravel pit, the site was used during the period between 1954 through 1985 for the disposal of construction debris generated during demolition of Hanford Site facilities. Principal components of the waste include concrete rubble, asphalt, and wood debris. Undocumented disposal of waste

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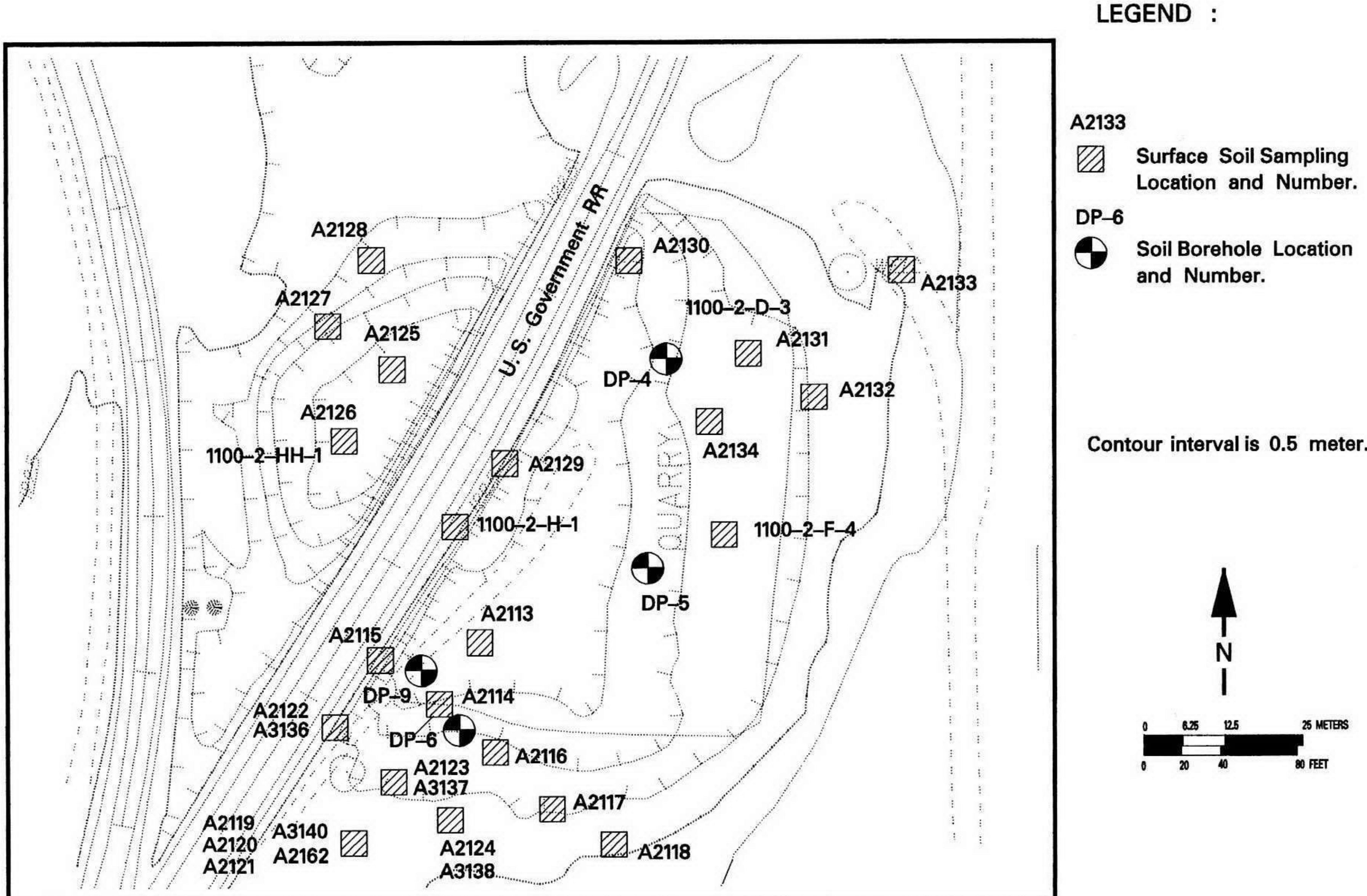


1100-2 Paint and Solvent Pit - Operable Subunit Soil Sampling Loacations.

Figure 3-2

paint, solvent, and paint thinner is also reported to have occurred at this site. The pit has an approximate diameter of 108 m (354 ft) and a depth of 1.2 to 1.8 m (4 to 6 ft).

The Paint and Solvent Pit floor consists of between 1.2 and 4.9 m (4 to 16 ft) of backfill mixed with asphalt debris derived from the construction of a nearby highway. A side spur of the Hanford Rail Line traverses the pit in a southwest-northeast direction isolating the northwest third of the pit from the remainder of the disposal site.

3.2.1 Vadose Zone Sampling

Four boreholes drilled at this site during the Phase I RI yielded 4 surface samples and 29 subsurface soil samples. In addition, soil samples were obtained at 20 surface locations within the 1100-2, Paint and Solvent Pit subunit (figure 3-2). Inorganic, organic and pesticide contamination was detected in surface and subsurface samples. Sampling and analysis methodologies and results are presented in the Phase I RI report (DOE/RL-90-18). Contaminants identified in surface soil samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Calcium	Chromium	Copper	Lead
Potassium	Sodium	Thallium	

<u>Organic Contaminants</u>

Chlorobenzene	Tetrachlorethene	Trichloroethene
1,1-dichloroethene	Xylene	

Contaminants identified in subsurface samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Calcium	Copper	Lead	Magnesium
Manganese	Potassium	Sodium	Zinc

<u>Organic Contaminants</u>

4,4'-DDE	4,4'-DDT	Tetrachloroethene

Soil sampling was not performed at the 1100-2, Paint and Solvent Pit subunit during the Phase II RI.

3.2.2 Geophysical Investigation

One geophysical survey was performed at the Paint and Solvent Pit during the Phase I investigation. Geophysical methods employed included EMI, MAG, MD, and GPR. The geophysical investigation covered an area of approximately 1.09 hectares (2.7 acres) during the months of January through April, 1989. The purpose was to obtain information regarding waste materials buried at the site, information regarding the location of waste disposal structures (pits and trenches), identification of any underground utilities that may cross the site, and identification of any other waste disposal-related features existing within the depression.

Waste materials identified within the Paint and Solvent Pit are concentrated in the eastern portion of the subunit. No waste deposits were evident in the portion of the pit west of the railroad tracks. A GPR reflector located at a depth of approximately 3.05 m (10 ft) appears to mark the bottom of the original pit. Based on surface observations, waste material consists predominantly of concrete and asphalt debris. Geophysical signatures indicating the presence of metals can be explained by the presence of reinforcing steel (rebar) within concrete blocks. None of the geophysical data suggest the presence of steel drums within the subunit. Waste deposits are covered by 0.61 to 1.52 m (2 to 5 feet) of soil. The only other features identified at the site were several abandoned metal irrigation pipes. Portions of these pipes are visible on the ground surface (Sandness *et. al.*, 1989).

No geophysical investigations were performed at the 1100-2, Paint and Solvent Pit during the Phase II RI.

3.2.3 Soil-Gas Investigation

Sixty-two temporary soil-gas probes were installed, sampled, and analyzed during the Phase I investigation, in February and March, 1989. One area of relatively high readings of tetrachloroethene (PCE) was found in the southwest corner of the site close to the end of a service road which extends back toward a railroad storage yard located immediately north of the Paint and Solvent Pit site. Concentration values peaked at 727 μg/L PCE with values steeply dropping in all directions away from the high. Areal distribution of the positive soil-gas readings suggested the potential for an isolated, shallow accumulation or small surface spill of solvent within the pit. However, no PCE was identified in any soil sample for this subunit. No other volatile contaminants were detected during the soil-gas survey (Evans, 1989).

Phase II investigations did not include any additional soil-gas monitoring at the 1100-2, Paint and Solvent Pit subunit.

3.2.4 Summary of Investigations

Site investigations at the 1100-2 subunit, Paint and Solvent Pit, detected inorganic, organic, and pesticide contamination in site soils. Geophysical surveys located several abandoned waterlines within and adjacent to the Paint and Solvent Pit. Other geophysical returns can be ascribed to reinforcing steel (rebar) within concrete blocks at the site. Geophysical data did not reveal the presence of buried drums. Soil-gas investigations detected an isolated area of PCE contamination in the southwest corner of the pit. However, no PCE was identified in any soil sample for this subunit.

3.3. ANTIFREEZE AND DEGREASER PIT-1100-3

The 1100-3, Antifreeze and Degreaser Pit is a shallow, roughly circular depression located approximately 1.6 km (1 mile) north of the 1171 Building on the west side of the Hanford Rail Line (figure 3-3). Originally a sand and gravel source for construction activities on the Hanford Site, it was used during the period of 1979 to 1985 as a disposal site for waste construction material, principally roofing and concrete rubble. The pit is approximately 76 m (250 ft) in diameter and 1.8 to 2.4 m (6 to 8 ft) deep. Occasional disposal of waste antifreeze and degreasing solutions from the 1171 Building is suspected, but not documented, at this location.

3.3.1 Vadose Zone Sampling

Twenty-three surface samples were collected and twenty-four subsurface samples were obtained from four boreholes at the 1100-3, Antifreeze and Degreaser Pit during the Phase I RI as outlined in DOE/RL-90-18 (figure 3-3). Inorganic contaminants were found in surface and subsurface samples. No organic contaminants were detected at the 1100-3 subunit. Contaminants identified in surface soil samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Aluminum	Calcium	Chromium	Copper
Lead	Sodium	Thallium	

<u>Organic Contaminants</u>
(None encountered)

Contaminants identified in subsurface samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

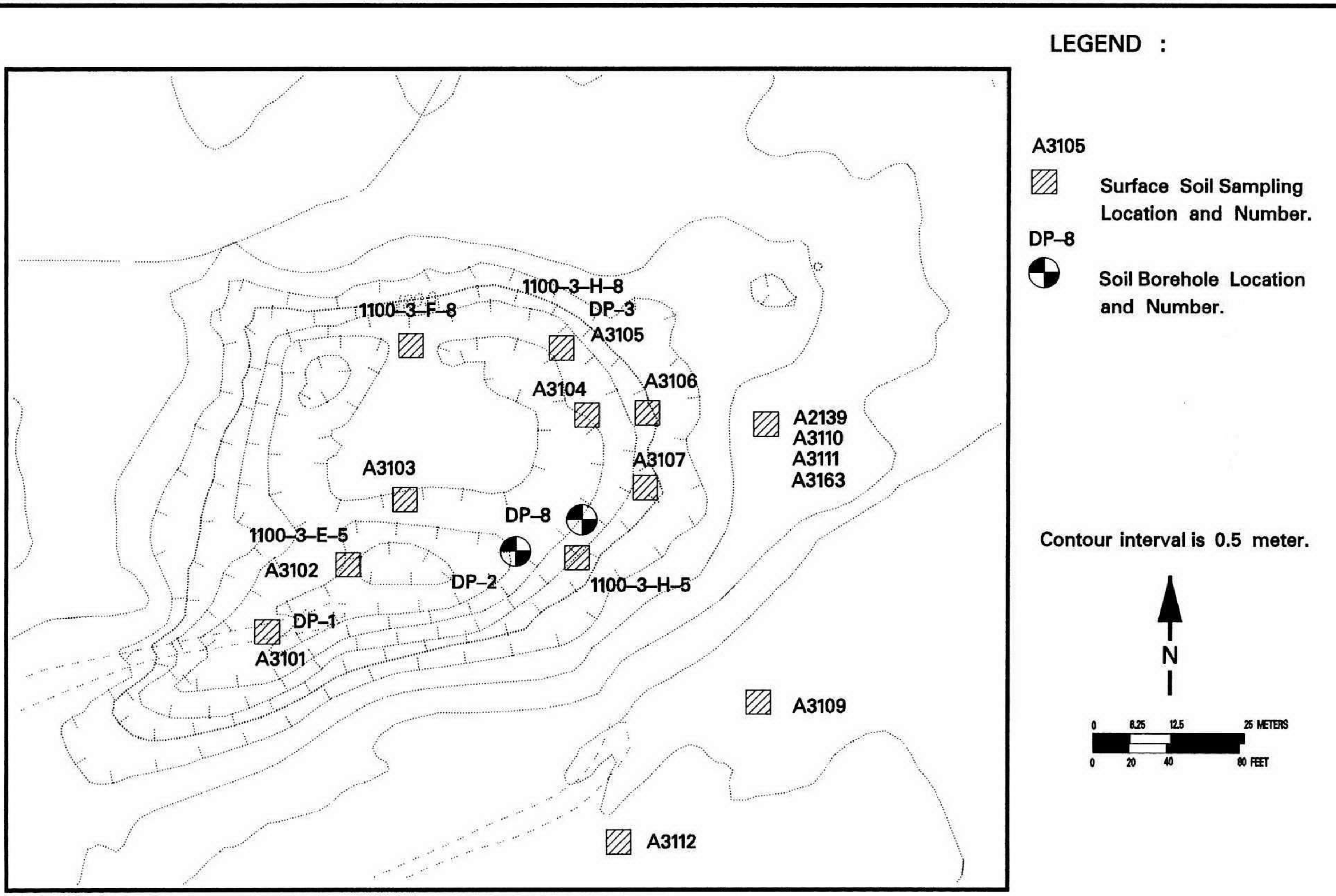
Aluminum	Calcium	Cobalt	Copper
Iron	Magnesium	Manganese	Sodium
Zinc			

<u>Organic Contaminants</u>
(None encountered)

No Phase II soil samples were taken at the 1100-3, Antifreeze and Degreaser Pit.

3.3.2 Geophysical Investigation

One geophysical survey was completed at the Antifreeze and Degreaser Pit during the Phase I investigation. Geophysical methods employed included EMI, MAG, MD, and GPR. The geophysical investigation, undertaken during the months of January through April 1989,



1100–3, Antifreeze and Degreaser Pit – Operable Subunit Soil Sampling Locations.

Figure 3–3

covered an area of approximately 1.5 hectares (3.7 acres). The purpose was to obtain information regarding waste materials buried at the site, to locate waste disposal structures (pits and trenches), to identify any underground utilities crossing the site, and to identify any other waste disposal-related features existing within the depression.

Waste materials within the Antifreeze and Degreaser Pit are concentrated in one large body and two smaller satellite bodies. The material appears to consist predominantly of concrete debris. As with the Paint and Solvent Pit, large metal signatures identified at the site likely result from reinforcing steel (rebar) within the concrete. None of the signatures indicate the presence of steel drums. Further conclusions regarding waste deposits at this site could not be made. A single abandoned tile pipe was identified in the vicinity of the pit (Sandness *et. al.*, 1989).

No geophysical investigations were performed at the 1100-3, Antifreeze and Degreaser Pit subunit during Phase II RI activities.

3.3.3 Soil-Gas Investigation

Forty-three soil-gas samples were collected during the Phase I RI from the Antifreeze and Degreaser Pit. Sample collection occurred during the months of May and June 1989. All sampling probes were temporary and were removed after the initial round of sampling was completed. No contaminants were detected during the soil-gas investigation (Evans, 1989).

Soil-gas sampling was not undertaken during the Phase II investigations of the 1100-EM-1 Operable Unit at 1100-3, the Paint and Solvent Pit.

3.3.4 Summary of Investigations

Site investigations at the 1100-3 subunit, Paint and Solvent Pit, detected inorganic contaminants in site soils. Geophysical investigations did not provide evidence for the presence of buried drums, however, a single abandoned tile pipe was detected. Soil-gas sampling failed to detect any contaminants at the 1100-3, Antifreeze and Degreaser Pit subunit.

3.4 ANTIFREEZE TANK SITE - 1100-4

The Antifreeze Tank Site is located beneath the concrete floor of the northern-most portion of the 1171 Building (figure 3-1). It is the former location of a 19,000 L (5,000 gal) steel, underground waste antifreeze storage tank. The tank was installed in 1976 and removed in 1986 due to suspected leakage. No evidence of leakage was detected during the removal operation.

3.4.1 Vadose Zone Sampling

During tank removal, three soil samples were collected from the base of the excavation. No detectable levels of antifreeze were identified. In November 1989, a hole was cut through the concrete floor of stall 89 inside the 1171 Building to allow sampling of the waste site. Thirteen vadose zone samples were collected and analyzed for the full suite of chemical analyses (TCL and TAL) including ethylene glycol. Only a single sample detected ethylene glycol at a concentration of 2.6 parts per million (ppm). Other than this single exception, only inorganic contaminants were detected at this site. Sample analysis results are reported in the Phase I RI report (DOE/RL-90-18). Contaminants identified in subsurface samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Aluminum	Arsenic	Beryllium	Calcium
Copper	Lead	Potassium	Silver
Sodium	Thallium	Zinc	

<u>Organic Contaminants</u>
Ethylene glycol

No surface data or soil samples were collected at the 1100-4, Antifreeze Tank Site during the Phase II investigations.

3.4.2 Summary of Investigations

Site investigations at the 1100-4 subunit, Antifreeze Tank Site, detected inorganic contaminants and a single organic contaminant in subunit soils.

3.5 DISCOLORED SOIL SITE - UN-1100-6

The Discolored Soil Site was identified during the RI Phase I scoping process as a patch of oily, dark stained soil located in the eastern end of an elongate east-west oriented depression approximately 610 m (2,000 ft) northwest of the 1171 Building on the west side of the Hanford Rail Line (figure 1-2). The depression extends over an area of approximately 0.2 hectares (0.4 acres); the actual area of discolored soil covering an area of perhaps 1.8 by 3.1 m (6 by 10 ft).

The southern boundary of the triangular-shaped depression consists of a steep slope apparently excavated in a natural sand dune. The northern boundary is defined by a similar steep slope comprised of material excavated during the construction of a northeast-southwest trending, concrete lined irrigation canal located immediately to the north of the bounding slope. The short eastern boundary of the Discolored Soil Site consists of the raised bed of a native-surfaced road that parallels the western edge of the Hanford Rail Line. The discoloration is located immediately adjacent to the eastern site boundary at the base of the road fill slope.

The source of the soil discoloration is conjectured to be the isolated, unauthorized disposal of contents of one or more containers of liquid material to the ground surface. No record exists that identifies the nature or origin of the waste of the material deposited at the site.

3.5.1 Vadose Zone Sampling

Fifteen surface samples were obtained from this site during the Phase I RI (figure 3-4). Analyses were for TAL and TCL parameters as described and reported in the Phase I RI report (DOE/RL-90-18). No subsurface sampling was performed. Inorganic, organic, and pesticide contamination was detected at this site. Contaminants identified in surface soil samples collected during the Phase I investigation included:

Inorganic Contaminants

Lead	Potassium	Zinc

Organic Contaminants

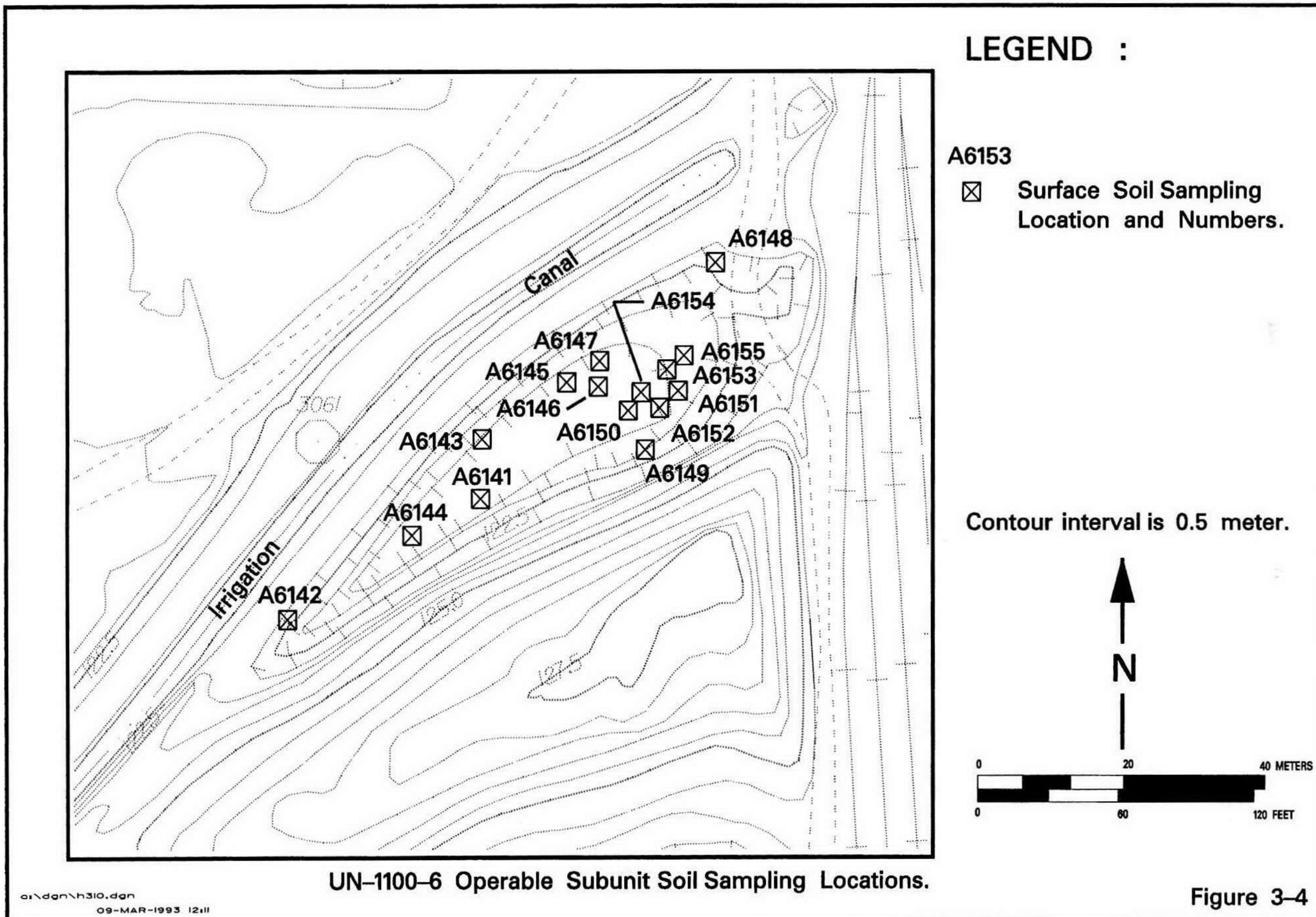
Alpha-chlordane	Gamma-chlordane	4,4'-DDE	BEHP
Heptachlor	2-hexanone	di-n-octyl phthalate	
1,1,1-trichloroethane			

The original work plan for the RI/FS stated soil sampling of this subunit would be performed for the purpose of identifying potential contaminants. After a thorough review of analytical results from the surface sampling and a field examination of the site, it was deemed to be an inefficient use of time given the project schedules and not cost effective to perform sampling of subsurface soils. The vertical extent of contamination will be determined during remediation by soil sampling and analysis (see sections 7 and 8). No soil samples were collected from the UN-1100-6, Discolored Soil Site, during the Phase II investigations.

3.5.2 Soil-Gas Investigation

Soil-gas sampling was not performed during the RI Phase I investigation of the UN-1100-6, Discolored Soil Site subunit.

Fourteen temporary soil-gas probes were installed at the Discolored Soil Site to depths ranging between 0.46 and 1.22 m (1.5 and 4 ft) during the Phase II investigation. The purpose was to investigate the possibility of a vadose zone source for contaminants identified during surface soil sampling/analysis. The installations occurred in November and December 1990. Target compounds were not detected in any of the soil-gas samples (WHC, 1991b).



UN–1100–6 Operable Subunit Soil Sampling Locations.

Figure 3–4

3.5.3 Summary of Investigations

Inorganic, organic, and pesticide contaminants were detected in soils of the UN-1100-6, Discolored Soil Site subunit at concentrations above UTL's. The vertical extent of contamination will be determined during remediation.

Target compounds were not detected during the soil-gas investigation.

3.6 EPHEMERAL POOL

The Ephemeral Pool is a long, narrow, manmade depression located along the western edge of the asphalt paved 1171 Building parking area (figure 1-2). The depression acts as a drainage collection point for precipitation runoff flowing from the parking area surface. It is bounded on the east by the parking facility and on the west by ballast of the Hanford Rail Line. On the north and south, the Ephemeral Pool boundaries are not as distinct. The bottom of the depression gradually rises toward both the north and south to near the elevation of surrounding land. Overall dimensions are approximately 6.1 m (20 ft) wide (east-west direction) by 183 to 213 m (600 to 700 ft) in length (north-south direction).

The Ephemeral Pool was designed to collect runoff from the parking area and direct it to a central culvert located approximately at the lengthwise mid-point of the depression. Settlement and/or poor grading of the depression floor results in the formation of a series of linked pools after rainfall events that temporarily hold a portion of the collected moisture within the drainage way until it evaporates or infiltrates into the ground. A pervious gravel lining encourages infiltration of the collected runoff into the vadose zone beneath this site.

3.6.1 Vadose Zone Sampling

3.6.1.1 Phase I Soil Sampling. The Phase I RI report describes the sampling and analytical results for two surface samples taken within the Ephemeral Pool. Results of the analyses indicated the presence of PCB's in low to moderate concentrations (300 to 4700 μg/kg). Contaminants identified in surface soil samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>		
Lead	Zinc	

<u>Organic Contaminants</u>		
Aroclor-1260	Alpha-Chlordane	Gamma-Chlordane
Endosulfan II	Endrin	Heptachlor

3.6.1.2 Phase II Soil Sampling. Six surface samples and one duplicate were obtained for the Phase II RI in order to delineate the lateral extent of organic contamination at the Ephemeral Pool (figure 3-5). The soil samples collected during the Phase II RI were

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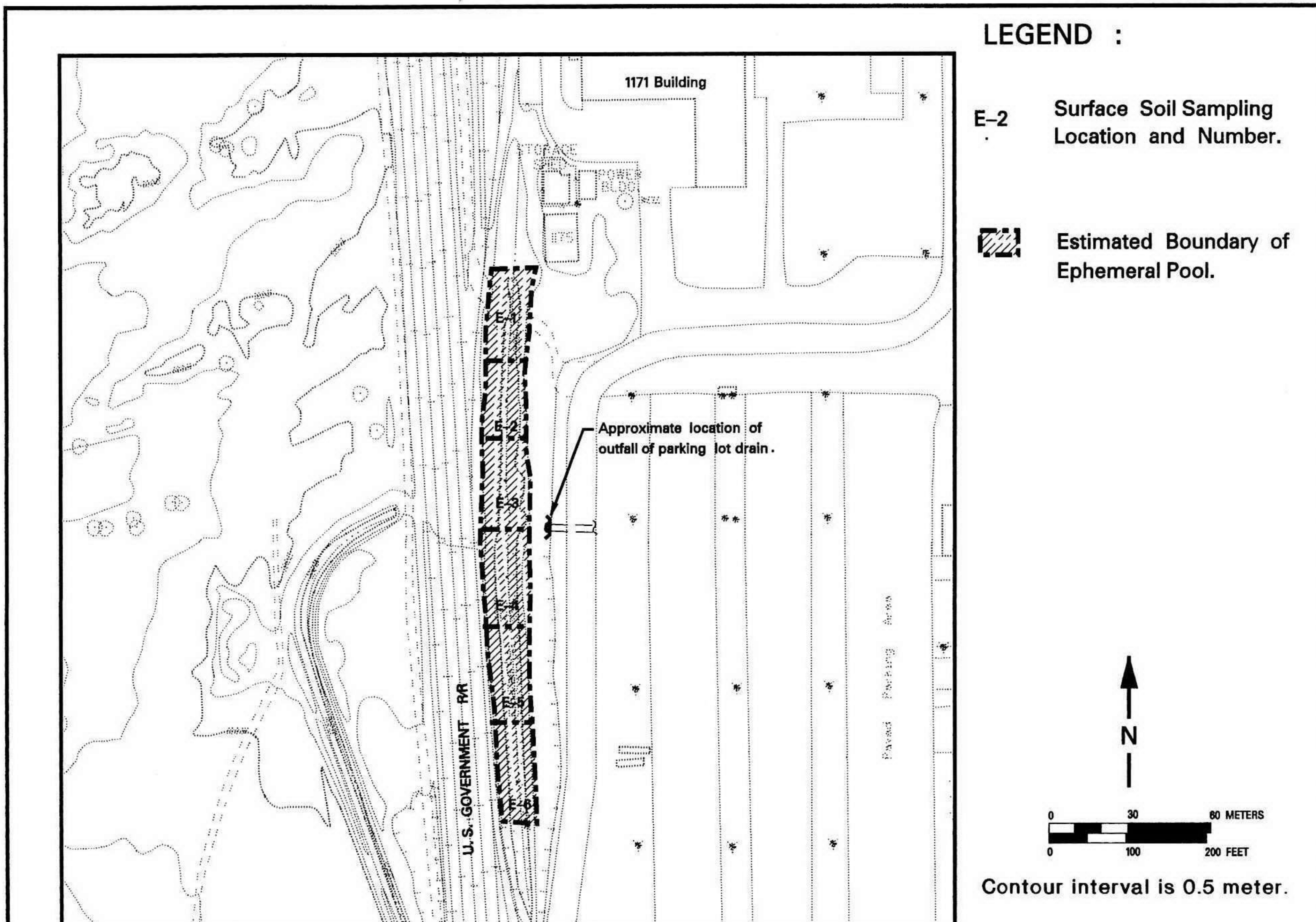

Ephemeral Pool Subunit Phase II Soil Sampling Locations.

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Figure 3-5

submitted for PCB and pesticide analyses. Laboratory results confirm the presence of alpha and gamma chlordane in concentrations of 210 to 1100 $\mu g/kg$ and 330 to 1700 $\mu g/kg$, respectively. Positive results for PCB's (Aroclor 1260) were obtained from two of the seven samples with concentrations of 11,000 and 42,000 $\mu g/kg$. Contaminants identified in surface soil samples collected during the Phase II investigation included:

Inorganic Contaminants
(Not analyzed)

Organic Contaminants

Chlordane[1]
Endosulfan II
Endrin
PCB's[2]

[1] alpha and gamma isomers combined for evaluation as total chlordane.
[2] all polychlorinated biphenyls combined for evaluation as total PCB's.

Analytical results are presented in appendix D.

3.6.2 Summary of Investigations

Organic and pesticide contamination of soils within the Ephemeral Pool subunit were detected at concentrations above UTL's.

3.7 HORN RAPIDS LANDFILL

The HRL, which is located northeast of the SPC facility and north of Horn Rapids Road, extends over approximately 20 hectares (50 acres) of the 600 Area (figure 1-2). It was operated from the late 1940's into the 1970's as an uncontrolled landfill.

The landfill is sited in generally flat terrain. Five partially to completely filled disposal trenches have been identified at the site through a study of historic aerial photographs, onsite investigations, and geophysical surveys. Surface debris consisting of auto and truck tires, wood, metal shavings, soft drink cans and bottles, and other small pieces of refuse are scattered across the site. A single trench, the western-most of the identified waste disposal trenches, was posted with signs warning that the feature contained asbestos.

3.7.1 Vadose Zone Sampling

3.7.1.1 Phase I Soil Sampling. Soil sampling at HRL was performed as described in the Phase I RI report (DOE/RL-90-18). Fourteen boreholes were advanced during the Phase I

RI at HRL. These boreholes yielded 63 discrete soil samples; 8 samples were obtained from the surface strata and 55 were obtained from the subsurface. Forty-two additional surface samples were taken from the landfill (figure 3-6). It should be noted that during the Phase I RI, boreholes were intentionally sited to avoid drilling through known and suspected waste deposits. This places substantial limitations on the representativeness of the soil quality results of the Phase I data.

Numerous inorganic, organic, pesticide, and PCB contaminants were encountered in the surface and subsurface soils of the HRL during the Phase I investigation. Contaminants identified in surface soil samples collected during the Phase I investigation included:

<u>Inorganic Contaminants</u>

Aluminum	Arsenic	Barium	Beryllium
Cadmium	Calcium	Chromium	Cobalt
Copper	Cyanide	Iron	Lead
Magnesium	Mercury	Nickel	Potassium
Silver	Sodium	Thallium	Zinc

<u>Organic Contaminants</u>

Aroclor-1248	Aroclor-1254	Alpha-Chlordane	4,4'-DDD
4,4'-DDE	4,4'-DDT	Heptachlor	2-methylnaphthalene
Naphthalene	Tetrachloroethene		

Contaminants identified in subsurface soil samples collected during the Phase I investigation at the HRL subunit included:

<u>Inorganic Contaminants</u>

Aluminum	Antimony	Arsenic	Barium
Beryllium	Cadmium	Calcium	Chromium
Cobalt	Copper	Cyanide	Iron
Lead	Magnesium	Mercury	Nickel
Potassium	Silver	Sodium	Thallium
Zinc			

<u>Organic Contaminants</u>

Aroclor-1248

3.7.1.2 Phase II Soil Sampling. Phase II sampling was performed in an attempt to further delineate pesticide and PCB contamination at HRL. Eight surface samples were taken from the vicinity of borehole HRL-4; PCB-1 to PCB-4 and PCB-1A to PCB-4A (figure 3-7). Fifteen samples were taken from the surface between depths of 0 and 0.7 m (0 and 2 ft) at pits 4 and 5; B4-1, B5-1, B5-2 and B5-3 (figure 3-8). Thirteen subsurface samples were

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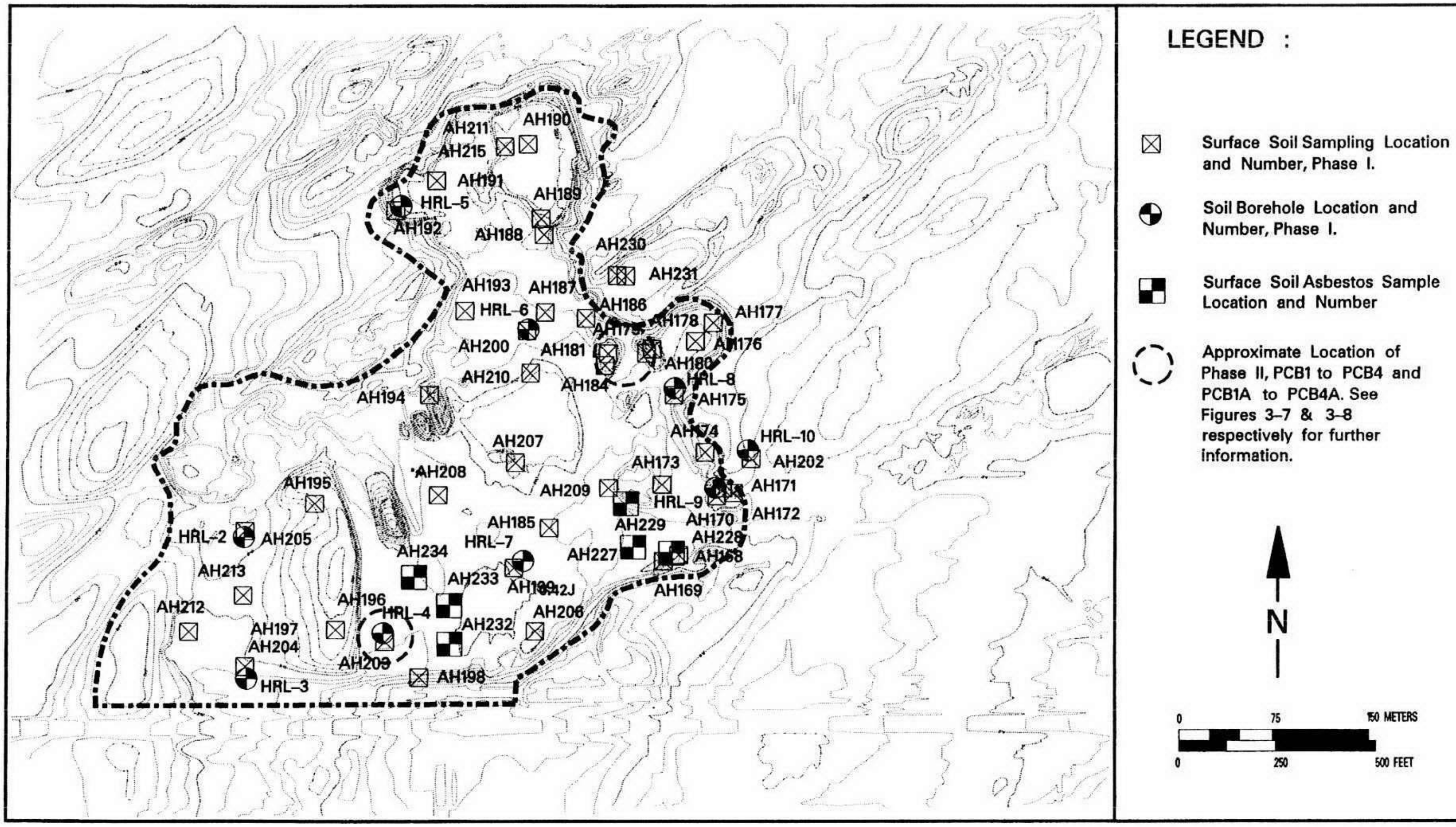

Contour interval is 0.5 meter.

Horn Rapids Landfill Subunit Soil Sampling Locations

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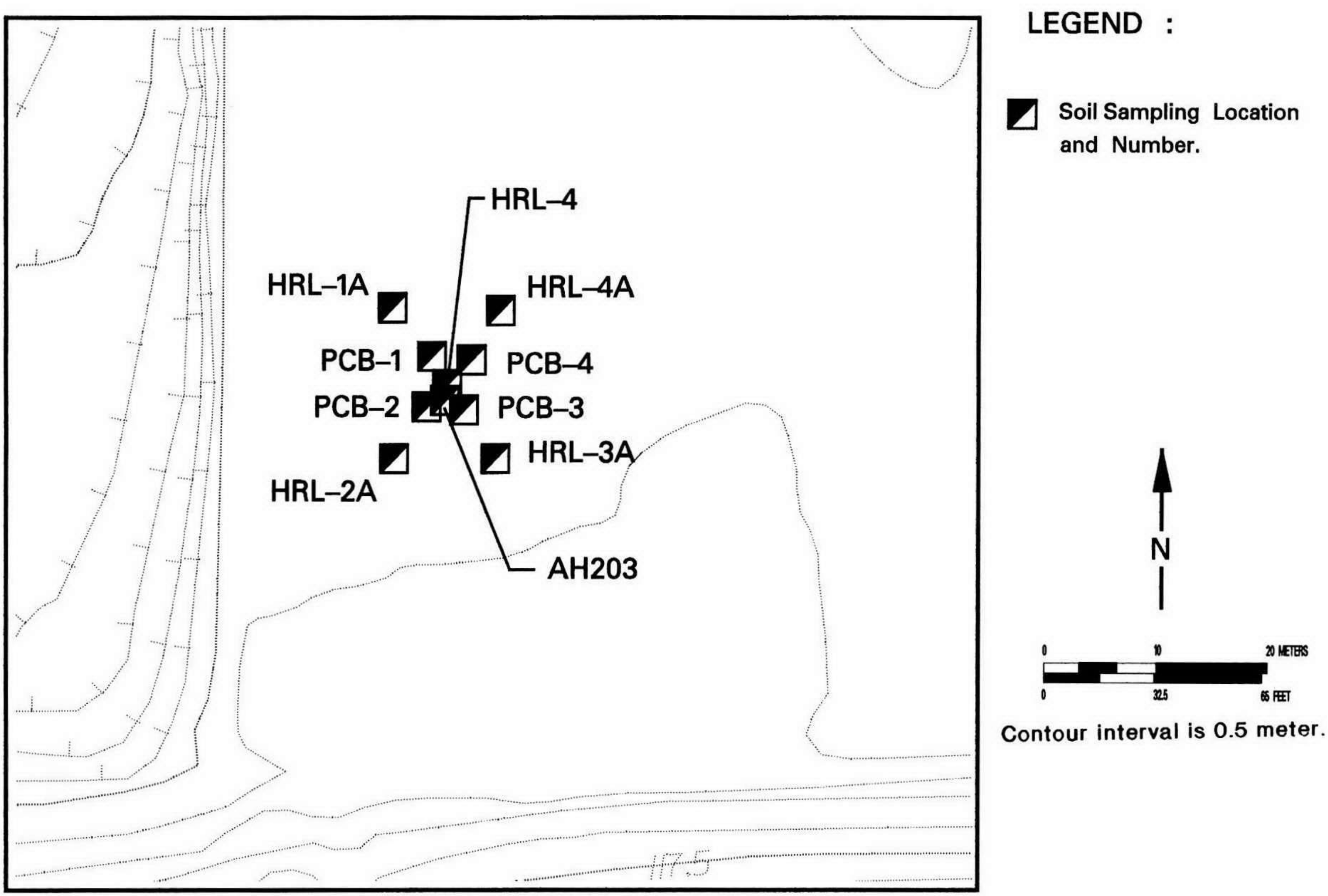
Figure 3-6



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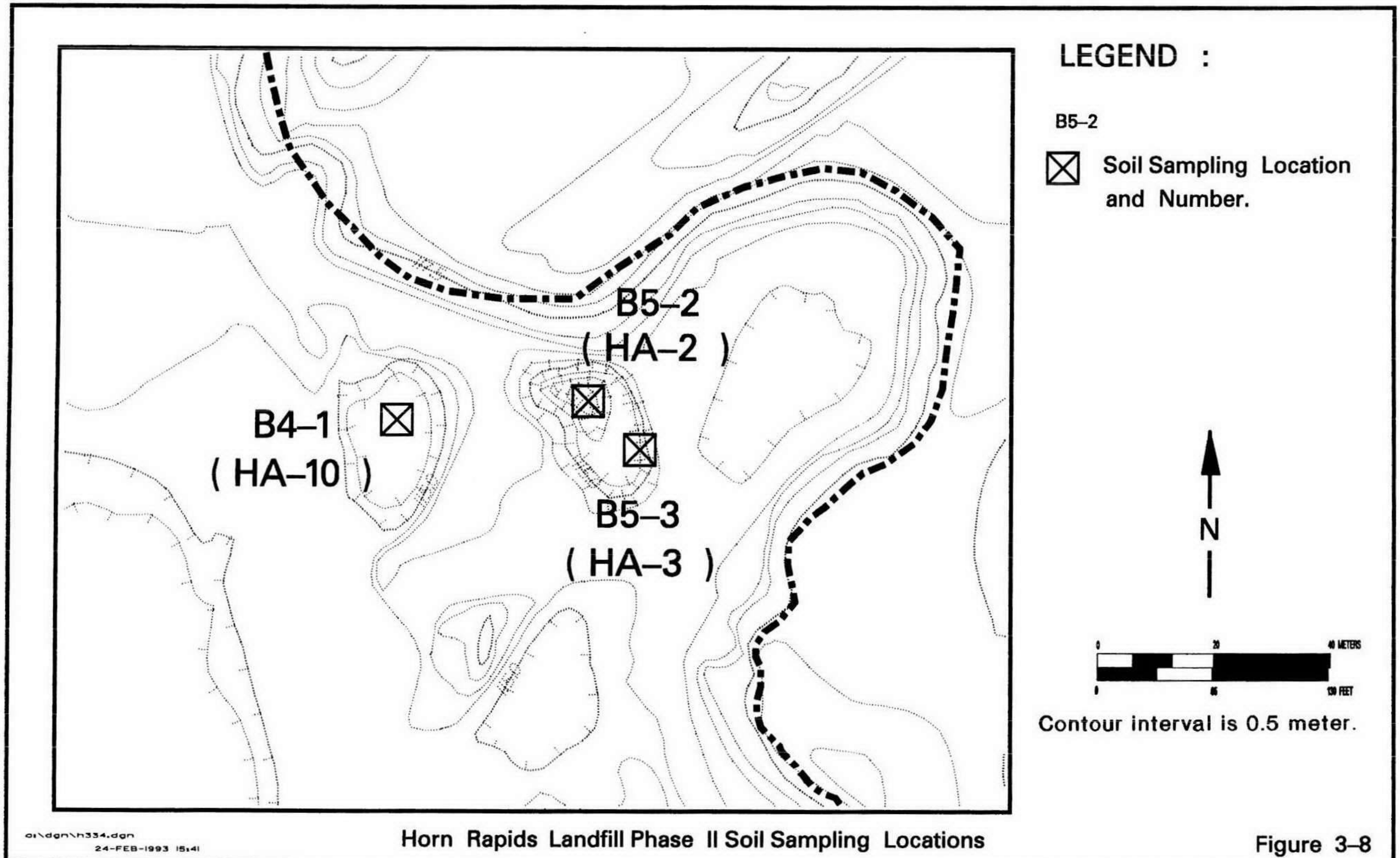
Horn Rapids Landfill Phase II Soil Sample Locations

Figure 3–7



Horn Rapids Landfill Phase II Soil Sampling Locations

Figure 3–8

taken during disposal trench characterization activities (see paragraph 3.7.4). Contaminants identified during Phase II soil analyses that were not detected above UTL's during the Phase I investigation include:

Surface	Subsurface
Inorganic Contaminants	Inorganic Contaminants
None encountered	Manganese
Organic Contaminants	Organic Contaminants
Endosulfan II	Dieldrin
Endrin	Total PCB's

3.7.2 Geophysical Investigations

Two separate geophysical surveys were performed at HRL as part of the Phase I and II RI. Phase I RI surveys employed EMI, MAG, MD, and GPR methods. The geophysical investigation for the Phase II RI employed EMI, MAG, and GPR surveys.

3.7.2.1 Phase I RI. The Phase I geophysical investigation covered an area of approximately 24.7 hectares (61 acres) during the months of January through April 1989. The purpose was to obtain information regarding waste materials buried at the site, to locate waste disposal structures (pits and trenches), to identify any underground utilities crossing the site, and to identify any other waste disposal-related features existing within the landfill. Survey lines were laid out with a 30.5 m (100 ft) spacing.

Due to the wide spacing of survey lines, little in the way of detailed data concerning the disposal trench contents was obtained. Based on GPR results, disposal trenches were interpreted as containing abundant waste metals to at least depths approaching 5.5 m (18 ft). Waste deposits were found to be concentrated in a roughly 6.9 hectare (17 acre) area in the south-central portion of the landfill. Outside of the five identified waste disposal trenches, no other major waste accumulations were detected, although the entire surface of the subunit is littered with miscellaneous debris. The landfill had apparently been a large sand and gravel pit prior to its use as a disposal facility. This conclusion was reached due to the absence of eolian dune sand throughout the surveyed area and the exposure of normally buried natural deposits of sand and gravels at the ground surface (Sandness, *et. al.*, 1989).

3.7.2.2 Phase II RI. The Phase II RI geophysical investigation at HRL was performed to further delineate disposal trench boundaries identified during the first geophysical surveys of the site and to search for an accumulation of drums containing organic solvents said to have been buried at this facility. During May 1991, EMI and MAG surveys were performed to delineate the trenches fully and to perform the initial search for drums. GPR was used to define the spacial extent, both vertically and laterally, of anomalies identified by the initial two geophysical methods (Golder, 1991).

A total of 4.7 hectares (11.7 acres) were surveyed. The EMI survey grid was performed along lines spaced 3.1 m (10 ft) east-west and 6.1 m (20 ft) north-south. The grid for MAG measurements was laid out on lines spaced 3.1 by 3.1 m (10 x 10 ft). The GPR survey was run over east-west lines spaced at 3.1 m (10 ft) intervals; each line ranging from 24.4 m (80 ft) to 121.9 m (400 ft) in length.

Anomalies identified by the EMI survey were located in the immediate vicinity of disposal trenches, adjacent to the burn cage located at the northern edge of the landfill and, finally, the burn cage itself was identified as an anomaly. MAG anomalies were generally coincident with those identified by EMI. Results obtained near the disposal trenches were interpreted as being caused by an abundance of shallow deposits of metallic debris buried within the features. The quantity of metallic debris was such that each disposal trench effectively registered as a single buried metal object (Golder, 1991). GPR survey results were less specific. Signal penetration outside the disposal trenches reached to depths of 4.9 to 6.1 m (16 to 20 ft). Fairly continuous stratigraphic boundaries were found to exist in these areas. In contrast, signal returns from directly over the disposal trenches were generally chaotic. Penetration into the subsurface was severely limited and irregular. A total of 253 targets were identified during the GPR survey, most at depths of between 1.5 and 3.1 m (5 to 10 ft).

The overall interpretation of the Phase II RI geophysical investigation at HRL identifies shallow deposits of metallic debris buried within the recognized disposal trenches. The EMI and MAG surveys identified several anomalies which were consistent with the presence of an accumulation of 10 or more drums. GPR surveys conducted over the target locations did not provide definitive data either for or against the possibility that the anomalies represented 10 or more buried drums. The 10-drum guideline was established by the regulators as the minimum number which would constitute a significant concentration of drums requiring even further investigations. Of the five trenches of concern, the asbestos trench, (the western-most and longest disposal trench which was posted with signs identifying the presence of asbestos-containing materials), was the least likely candidate to contain buried drums based on geophysical survey results (Golder, 1991). Excavation into the deposits was recommended as the only means to definitively identify the exact nature of the geophysical targets located during the survey.

3.7.3 Soil-Gas Investigations

Soil-gas studies were performed at HRL and in surrounding areas during both the Phase I and Phase II RI utilizing permanent and temporary soil-gas extraction points. All permanent soil-gas probes were installed during the Phase I investigation. Monitoring of permanent probes continued through the Phase II investigations at HRL. Purposes of the soil-gas monitoring included the preliminary delineation of the groundwater contaminant plume located beneath the Horn Rapids area to assist in siting permanent groundwater monitoring wells; a survey of the vadose zone for a possible contaminant source contributing to groundwater quality degradation; and, evaluation of the sensitivity of soil-gas monitoring and its usefulness to define accurately the extent and rate of growth of a groundwater contaminant plume. A summary of the results of each is presented in the following paragraphs. Detailed results of soil-gas sampling activities performed at HRL can be found in Evans, 1989 and Golder Associates, 1992.

3.7.3.1 Delineation of Groundwater Contaminant Plume. The first stage of preliminary soil-gas sampling performed at HRL was for the purpose of scoping work for future RI sampling activities. Two hundred and eleven temporary soil-gas extraction points were installed in the landfill area to depths between 1.1 and 1.2 m (3.5 and 4.0 ft) during the period of March through May, 1989. Evidence of contamination by several chlorinated species including trichloroethene (TCE); 1,1,1-trichloroethane (TCA); and PCE was found within the HRL. TCE was widespread on the east side of the landfill and was found in a narrow plume extending from the southern boundary northwards toward the center of the landfill. A small area with positive TCA readings is coincident with the TCE plume which extends from the landfill's southern boundary. A region of positive PCE readings is located approximately 152 m (500 ft) east of the TCE maximum (Evans, 1989). Results of this preliminary scoping study were used to determine the siting of subsequent groundwater monitoring wells installed near HRL during the Phase I RI.

During the second stage of RI sampling, a total of 53 additional sampling probes were installed, sampled, and analyzed to delineate the TCE plume previously identified in the vicinity of HRL. The probes were temporary, installed to an approximate 1.2 m (4.0 ft) sampling depth, and were removed immediately after sampling had been completed. They extended from an area near the SPC pretreatment ponds to approximately 610 m (2,000 ft) northeast of the landfill center. TCE was detected at concentrations from 2 to 255 parts per billion by volume (ppbv) in 36 of the 53 probes. The highest TCE concentrations were obtained just outside the disturbed portions at the eastern limits of HRL. Results obtained from this stage of soil-gas monitoring were used in the siting of groundwater monitoring wells MW-19, MW-20, MW-21, and MW-22 installed during the Phase II investigation.

3.7.3.2 Vadose Zone Contaminant Source Investigation. A total of 36 permanent soil-gas extraction points were installed within the limits of HRL during the period between December, 1990 and February, 1991. In addition, forty temporary extraction points were placed within the South Pit, immediately south of the landfill across Horn Rapids Road, between November and December, 1990. South Pit was a satellite facility associated with HRL (figure 1-2). Disposal trenches within the South Pit area have been observed on aerial photographs taken throughout the operating history of the Hanford Site. Like HRL, waste disposal at South Pit was unregulated and undocumented. Waste material, (as evidenced by surface observations, the study of aerial photographs, and geophysical surveys), is assumed to be similar to that found at the Horn Rapids facility. Since the groundwater contaminant plume skirts South Pit, it was included in the investigation as containing a possible vadose zone source for the groundwater contaminants. The purpose of these soil gas probe installations was to investigate the possibility of a vadose zone contaminant source that is contributing to the degradation of the underlying groundwater.

TCE was detected in 38 of the 40 temporary soil-gas extraction points sampled in South Pit. Concentrations ranged from 5 to 394 ppbv. Of the 36 permanent soil-gas probes installed within HRL, TCE was detected at 17 locations with concentrations ranging from 3 to 233 ppbv. These results strongly suggest that a vadose zone source for TCE or any other volatile organic compound is not present within HRL or South Pit. The concentration measured was far below that expected if a free source of the contaminant existed within the vadose zone. An approximate concentration for TCE in the vadose zone soil-gas, if present as a free source, can be estimated from its vapor pressure (EPA, 1987). The concentration immediately above the source would be expected to be 7 percent, or 70,000,000 ppbv. This is determined by taking the vapor pressure of TCE divided by the sum of the vapor pressure and atmospheric pressure:

$$7 \text{ percent TCE per liter of air} = (60/(60+760))*100$$

where 60 is the TCE vapor pressure (in mm Hg at 25°C) and 760 is atmospheric pressure (in mm Hg at sea level and 25°C). Sample results at HRL indicate TCE levels from nondetect to 394 ppbv as compared to an estimated maximum of 70,000,000 ppbv if a liquid TCE source were present near any of the sampling locations (Golder, 1992).

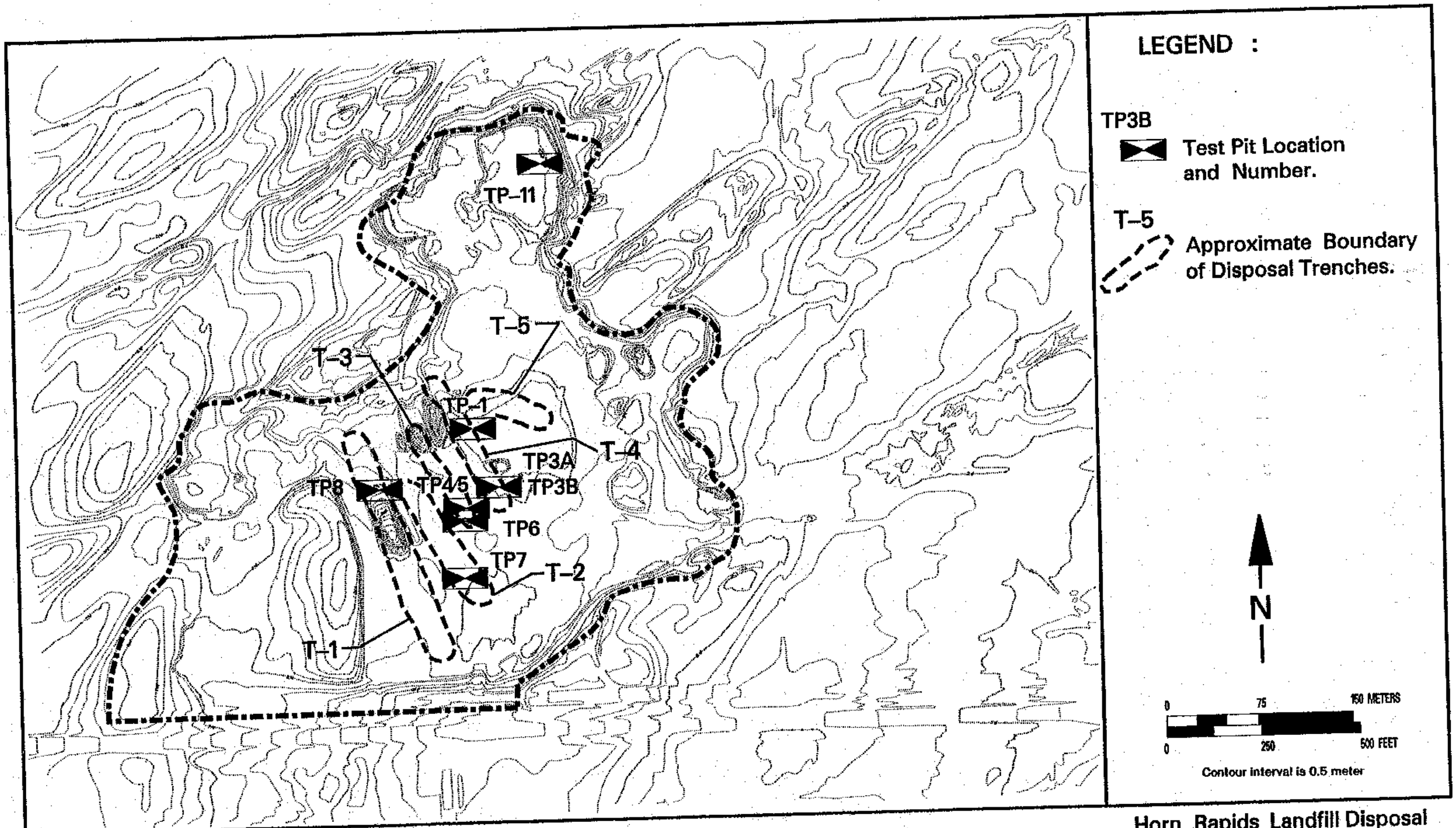
3.7.4 Disposal Trench Characterization

Anecdotal information gathered during the Phase I RI, suggested a quantity of up to 200 drums of carbon tetrachloride (CCl_4) may have been buried in one of the disposal trenches located within HRL. Golder Associates, Inc., performed a suite of geophysical surveys at the landfill including EMI, GPR, and MAG during May, 1991. Survey results discounted the anecdotal reports and did not present evidence for the presence of a large (greater than 10) accumulation of drums buried within the landfill facility. However, EPA and Ecology directed that the largest of the geophysical anomalies, representing the possible accumulation of 10 or more drums, be investigated and the known disposal trenches at the landfill be characterized (Unit Manager's Meeting minutes, January 14, 1991, S.W. Clark, WHC to R.K. Stewart, DOE). Eight exploration trenches were excavated within the landfill debris trenches during September and October 1991 to complete these tasks (figure 3-9). Exploration trenches were sited based on the location of the largest anomalies discovered during the geophysical survey and trench depths were planned to intercept the particular anomaly in question. Geologic logs of the test pits are provided in appendix A.

3.7.4.1 Soils. The soil matrix within all trench excavations consisted of sandy gravel having a fairly uniform composition averaging 53 percent gravel, 44 percent sand, and less than 4 percent silt. Soil structure was lacking in the gravel deposits as they likely have been repeatedly reworked by heavy equipment during debris burial operations throughout the life of the landfill facility. A deposit of 100 percent fine to medium sand was encountered below a depth of 13 feet within Trench No. 3A. The material appeared to be in an undisturbed state. Structural details of the sand deposit were unrecognizable due to the depth of the trench. The excessive sloughing of the excavation sidewalls prohibited safe trench entry for site personnel to inspect details of the deposit. All soil material encountered is interpreted as belonging to the Hanford formation. Trench depths, soil gradations and classification, and the percentage of soil versus debris encountered in each trench is presented in table 3-3.

3.7.4.2 Debris. Debris encountered during trench excavation can be roughly grouped into six categories; automotive, shop, construction, miscellaneous, medical, and unknown.

3.7.4.2.1 <u>Automotive Debris</u>--Automotive debris consisting of car and truck tires, mufflers, lengths of tail pipe, and inner tubes was found in all areas of the landfill. However, the



Horn Rapids Landfill Disposal Characterization Exploration Trench Locations

Figure 3-9

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TABLE 3-3: DEBRIS TRENCH COMPOSITION
HORN RAPIDS LANDFILL CHARACTERIZATION
1100-EM-1 OPERABLE UNIT

	DEPTH (FT)	SAND (%)	GRAVEL (%)	SILT (%)	SOIL (%)	DEBRIS (%)	SOIL CLASSIFICATION (after Folk, 1954)
Trench #1	0-11	43	52	5	90	10	Sandy Gravel
Trench #3A	1-13	40	55	<5	97	3	Sandy Gravel
	13-21	100	0	0	100	0	Sand
Trench #3B	0-8	52	44	4	97	3	Sandy Gravel
Trench #4/5	0-0.5	35	60	5	100	0	Silty Sandy Gravel
	0.5-12	45	55	<3	99.5	0.5	Sandy Gravel
Trench #6	0-6.5	35	65	<2	95	5	Sandy Gravel
Trench #7	0-6	52	43	0	85	15	Sandy Gravel
Trench #8	0-5	30	65	<5	98	2	Sandy Gravel
Trench #11	0-5	54	40	6	N/R	N/R	Sandy Gravel

Notes: 1. N/R – Results not reported in boring logs.

highest concentration of automotive debris relative to other debris types seemed to be in the central portion of the landfill area. Most of the automotive debris appeared to have been randomly dumped into the debris trenches. Tires may have occasionally been laced prior to burial, *i.e.*, carefully stacked to conserve space when large quantities were involved.

3.7.4.2.2 Shop Debris--Shop debris is characterized by accumulations of stainless steel lathe shavings, again concentrated in the central area of the landfill property. Large quantities of the material seem to have been haphazardly dumped into the debris trenches while smaller quantities appear to have been spread into distinct layers. The metal has a fresh appearance, with little or no deterioration apparent.

3.7.4.2.3 Construction Debris--Construction debris consisted of a variety of material including: metal flashing strips of various lengths, pieces of gypsum wallboard, roofing material, metal culverts, concrete, reinforcing steel (rebar), piping, steel cable, electrical wiring, asbestos and fiberglass insulation, and timbers. This material was uncovered in varying amounts in all eight of the characterization trenches. There was no apparent preferential disposal of this material although construction debris seemed to occur in associations. Metal flashing, gypsum wallboard, and fiberglass insulation were usually in close proximity to each other as were piping, cable, and asbestos insulation. Metal culvert lengths were found with concrete slabs and asphalt debris. Asphalt debris was usually present with roofing paper. All the materials were apparently collected during demolition activities and brought directly to the landfill for disposal.

3.7.4.2.4 Miscellaneous Debris--Miscellaneous debris includes all other types of material: soda bottles, paint containers, trash cans, coffee cans, cigarette butts, cloth, ash, and other items. The greatest abundance of this material was observed in the northern portion of the landfill, adjacent to the burn cage. Paint containers seemed to be concentrated in the central portion of the landfill area.

3.7.4.2.5 Medical Debris--One unique association of debris was encountered during the excavation of Trench No. 6. Medical debris consisting of between 30 and 40 multi-injection vials containing a milky white substance, a single plastic intravenous-dispenser bag, an "eye-dropper" bottle containing a clear liquid, one multi-injection vial containing a clear liquid, one 1.8 to 2.0 cm long by 1.0 cm diameter (7- to 8-inch long by 4-inch diameter) cylindrical bottle containing a clear liquid, and a metal sign indicating "Health Operation Medical Services" were uncovered at a depth of approximately 2.0 m (6.5 feet). No intact labels were present on any of the bottles or vials.

The majority of the material went undiscovered until backfilling operations had commenced and site workers were specifically alerted to watch for the presence of medical waste in the spoils pile. The medical debris was initially discovered when multi-injection vials were observed to fall from the backhoe bucket while it was being swung to the spoils pile. Trench excavation was immediately stopped when the medical debris was noticed due to the unknown hazards associated with the material. Based on visual inspection by Pacific Northwest Laboratory personnel, the milky white liquid material was very tentatively identified as some form of penicillin; likely surplus stock from a hospital or other medical facility. No identification was made for the clear liquids.

None of the medical debris was submitted for laboratory identification because no onsite laboratory could be located that was willing or capable of accepting medical materials for analysis. Offsite laboratories were inaccessible for analysis of the medical debris because the contents of the containers could not be certified by the health physics staff as being radiation-free and thus could not be released for offsite shipment. Therefore, a definitive identification of the pharmaceutical contained in the vials and bottles was not obtained. As excavation was stopped immediately after the discovery of the debris, the total extent of other medical products which may be present was not determined. Regulators were notified of the discovery and concurred with a proposal that all medical debris, chemical soil samples, and soil screening samples collected from this excavation be placed in the bottom of the trench and reburied [Unit Manager's Meeting minutes, October 31, 1991, from J. Stewart, (USACE) to R. Stewart, (DOE)]. Only a very small volume of medical debris was discovered.

3.7.4.2.6 Unknown Debris--Two unknown waste substances were uncovered during the excavation of Trench #3A; a white crystalline powder, and an isolated pocket of bright purple, stained soil.

3.7.4.2.6.1 White Crystalline Powder--The white crystalline powder appeared to have been originally contained in plastic-lined paper bags, resembling concrete bags in size and shape. Labelling on the bags was illegible. The material was placed in the debris trench in layers. Field screening of the substance proved negative for radiation and volatile organics. A suggestion was made by site workers that the material had the appearance of commercial fertilizer.

Chemical analysis performed during field screening of the sample using a HAZCAT® kit tentatively identified the substance as sodium bisulfate. The identification was based on the following:

- The substance is water soluble.
- Water pH after dissolution of the substance is <2.0.
- When a wire coated with the substance is introduced into a flame, the flame color turns yellow.
- When heated, the substance liberates sulfur dioxide.

A sample was subsequently analyzed at the Corps of Engineers North Pacific Division Laboratory in Troutdale, Oregon. Laboratory analysis confirmed the field screening results (see appendix D). Laboratory results are limited due to the fact that the sample chain-of-custody was broken. This was a routine laboratory analysis not performed under Contract Laboratory Procedure (CLP) protocols. No additional sampling is anticipated as available results provide sufficient assurance that no significant health and environmental threat is posed by this substance.

3.7.4.2.6.2 Stained Soil--Soil excavated from a depth of approximately 3.1 m (10 ft) in Trench No. 3A was stained bright purple. The stained soil was first noted in materials removed from the excavation by the backhoe bucket. Approximately 0.06 to 0.08 m^3 (2 to 3 ft^3) of stained soil was observed. Subsequent scoops failed to remove additional similar material and no staining was observed within the exploration trench. Field screening of the stained soil was negative for radiation and volatile organics. No source for the staining was observed. The site safety officer on duty during the discovery suggested the staining may have occurred due to the disposal of a permanganate compound.

Chemical analysis performed during field screening using a HAZCAT® kit provided a preliminary identification of the substance as potassium permanganate. The identification was based on the following:

- The substance is water soluble.
- The substance dissolves in alcohol.
- The sample provides a positive char test for the presence of manganese.
- The flame test for the presence of potassium was inconclusive due to difficulties in discerning changes in the flame color.
- The purple color is a characteristic of permanganate.

The sample was subsequently analyzed at the U.S. Army Corps of Engineers North Pacific Division Laboratory in Troutdale, Oregon (see appendix D). Laboratory analysis confirmed the field screening results. Laboratory results are limited due to the fact that the sample chain-of-custody was compromised. Again, this was a routine laboratory analysis not performed under CLP protocols. As with the white powder, available results provide sufficient assurance that no significant health or environmental threat is posed by the stained soil.

3.7.4.3 Field Screening. Field screening was performed continuously during the excavation of exploration trenches within the HRL. Soils were screened for organic vapors and for the presence of asbestos-containing materials (ACM). Air was monitored for the presence of asbestos fibers. Splits of soil samples collected for laboratory analysis were screened for the presence of heavy metals with a portable X-ray fluorescence (XRF) analyzer.

3.7.4.3.1 Organic Vapors--Soil and debris were continuously monitored with an oxygen/explosive level indicator and an organic vapor monitor (OVM) throughout the excavation process. A single positive OVM reading occurred in Trench No. 1 associated with a paint can and paint residue. The can and residue were collected, drummed, moved offsite, and disposed. At all other times, readings were negative.

3.7.4.3.2 Air Monitoring--Air monitoring for asbestos was implemented due to known past disposal of ACM at HRL and the discovery of asbestos waste during excavation of exploration Trench No. 1. Site-wide monitoring equipment was located at the edge of each control zone, downwind from the excavation. Personal air monitors were worn by personnel required to enter the control zones. Both types of monitors were checked daily. Asbestos detected by the monitors was below action levels in all cases.

3.7.4.3.3 Asbestos Debris Monitoring--Field personnel were constantly monitoring excavations and spoil piles for the presence of ACM. Suspect material was collected by the site geologist and/or the site safety officer and forwarded to the Hanford Environmental

Health Foundation (HEHF) laboratories for analysis. All suspect material collected and analyzed proved to contain asbestos although only a single debris trench was signed as containing asbestos. There seemed to be no pattern to the location of ACM within the landfill. Virtually all of the material appeared to have been piping insulation. Much of the asbestos material collected and analyzed was in a friable state.

3.7.4.3.4 XRF Monitoring--As noted above, soil samples collected for laboratory analysis were also subjected to screening by an XRF device. An X-Met 880© portable XRF analyzer was used to evaluate the samples for the presence of heavy metal contamination. Anomalous concentrations of iron were identified in many of the samples submitted for analysis. However, it was not determined whether the anomalies were the result of anthropogenic contamination or the result of natural variations in the iron content of HRL soils. Two samples revealed anomalous concentrations of copper and zinc. Laboratory analyses confirmed the field screening results, but concentrations were at levels below regulatory cleanup levels. XRF screening was performed as part of a Hanford Site-wide study to determine the utility of XRF screening techniques to environmental projects. Data collected by XRF screening were not utilized in the 1100-EM-1 Operable Unit analyses for the identification of potential site contamination.

3.7.4.4 Conclusions. Excavations at HRL confirmed the geophysical survey interpretation that a large accumulation of drums are not buried within the facility. Geophysical magnetic anomalies were found to represent accumulations of metallic objects including automotive debris, sheet metal, and metallic lathe shavings. Ground penetrating radar reflections could be explained by large, flat-lying pieces of sheet metal and automotive debris such as large truck mufflers. Asbestos-containing pipe insulation was the single hazardous material identified at the site. CCl_4 was not detected in any of the soil samples obtained from HRL during the Phase II investigation.

Medical waste discovered in Trench No. 6 will remain buried. Identification of two unknown substances, a white crystalline powder and soil stained a bright purple color, were confirmed by laboratory testing to contain sodium bisulfate and potassium permanganate, respectively. The medical waste, sodium bisulfate, and the potassium permanganate are not believed to represent an imminent threat to human health or the environment.

3.7.5 Summary of Subunit Soil Investigations

Inorganic, organic, and pesticide contamination was detected in soils at HRL subunit. Geophysical surveys conducted at HRL detected numerous anomalous readings in the vicinity of waste disposal trenches. None of the anomalies, however, were consistent with the presence of buried drums. Soil-gas readings detected TCE, TCA, and PCE vapors. Concentrations were far below those to be expected if a free source of the contaminants existed within the vadose zone. Waste disposal trench explorations failed to locate drums containing organic liquids. Debris within the waste disposal trenches fit into six broad categories including automotive debris, shop debris, construction debris, miscellaneous debris, medical waste, and unidentified waste. Asbestos was the single hazardous substance positively identified during waste disposal trench characterization.

3.8 SUMMARY OF 1100-EM-1 SOIL INVESTIGATIONS

Phase I surface and soil investigations included radiological surveys, geophysical surveys, several soil-gas surveys, soil sampling, and laboratory analysis of soil samples. Several subunits were identified with such a limited extent of contamination that little-to-no-further work was conducted (*e.g.*, subunits 1100-1, 1100-2, 1100-3, and 1100-4). The bulk of the Phase I analytical data was presented in the appendices of DOE/RL-90-18. Additional technical data is located in several referenced WHC publications (*e.g.*, soil gas reports).

Phase II surface and soil investigations focussed on additional characterization of the Ephemeral Pool and HRL. Additional soil samples were analyzed with data presented in appendix D. At the Ephemeral Pool and HRL, PCB's were measured in several samples.

Maximum values of all analytes at each subunit were presented for soils in tables 3-1 and 3-2. These values were compared with site-wide UTL's or background to identify contaminants. These tabulated lists were further screened to remove essential micronutrients. At the concentrations measured, aluminum, calcium, iron, magnesium, potassium, and sodium are nontoxic and do not pose a human health or an environmental threat (EPA, 1989A).

The remaining soil contaminants are used for risk-based screening in subsequent sections. In addition, where available, above background values were compared with published cleanup criteria. These soil contaminants are presented in table 3-4.

3.9 GROUNDWATER INVESTIGATIONS

Eleven full rounds of groundwater sampling have been completed at the 1100-EM-1 Operable Unit between January 1990 and the present. All analytical data available for groundwater sampling rounds 1 through 4 are presented in DOE/RL-90-18 and WHC 1990. Groundwater contaminants detected in concentrations exceeding background values were identified in DOE/RL-90-18 in WHC 1990. Analyses for groundwater samples collected during the first two sampling rounds included those analytes identified in the TAL, TCL, WAC 173-304, RCRA, and primary and relevant secondary drinking water parameters.

More detailed characterization of groundwater in the 1100-EM-1 Operable Unit was performed during Phase II investigations. The scope of the additional characterization was negotiated between DOE, Ecology, and EPA, and was finalized on July 24, 1991. DOE and the regulatory agencies agreed: that further hydrogeological investigations would include SPC property; that pump testing proposed by the U.S. Army Corps of Engineers, Walla Walla District to determine parameters for the unconfined aquifer in the vicinity of HRL for entry into the groundwater flow and transport model would not be performed; that monitoring wells MW-8 and MW-9, located along the western HRL boundary, would be used to establish background water quality for HRL; that monitoring wells MW-18, MW-19, MW-20, and MW-21 would be constructed within the Operable Unit for the purposes of this final RI/FS-(EA) report; and a limited groundwater sampling effort would be undertaken to investigate potential VOC contamination emanating from 1100-2, the Paint and Solvent Pit.

Table 3-4. Summary of 1100-EM-1 Operable Unit Soil Contaminants of Potential Concern and Maximum Contaminant Concentrations. (sheet 1 of 1)

Contaminant	1100-1 (mg/kg)	1100-2 (mg/kg)	1100-3 (mg/kg)	1100-4 (mg/kg)	Discolored Soil Site (UN-1100-6) (mg/kg)	Horn Rapids Landfill (mg/kg)	Ephemeral Pool (mg/kg)
Antimony	--	--	--	--	--	15.6	--
Arsenic	3.2	--	--	5.3	--	6.6	--
Barium	--	--	--	--	--	1,320	--
Beryllium	--	--	--	0.93	--	1.3	--
Cadmium	--	--	--	--	--	2.4	--
Chromium	--	16.8	14	--	--	1,250	--
Cobalt	--	--	17.8	--	--	42.5	--
Copper	37.9	24.4	31.7	19.3	--	1,280	--
Cyanide	--	--	--	--	--	0.56	--
Lead	266	94.6	26.4	5.7	22.1	854	54.2
Manganese	--	366	436	--	--	501	--
Mercury	0.39	--	--	--	--	1.3	--
Nickel	20.9	--	--	--	--	557	--
Selenium	--	--	--	--	--	0.97	--
Silver	--	--	--	2	--	7.7	--
Thallium	--	0.48	0.4	0.48	--	3.1	--
Vanadium	118	--	--	--	--	101	--
Zinc	100	56.6	60	63.8	111	3,180	67.5
BEHP	--	--	--	--	25,000	--	--
Beta-HCH	--	--	--	--	--	0.094	--
Chlordane	--	--	--	--	1.86	--	2.9
Chlorobenzene	--	0.006	--	--	--	--	--
DDT	--	0.16	--	--	0.17	1.98	--
Endosulfan II	--	--	--	--	--	0.11	0.16
Endrin	--	--	--	--	--	0.42	0.039
Heptachlor	--	--	--	--	0.065	0.02	0.029
2-Hexanone	--	--	--	--	0.053	--	--
Naphthalene	--	--	--	--	--	8.2	--
PCB's	--	--	--	--	--	100	42
Tetrachloroethene	--	0.035	--	--	--	0.006	--
Trichloroethene	--	0.006	--	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--	0.035	--	--

-- Indicates not a contaminant at this subunit
Note: This table includes data from the Phase I RI and Phase II RI.

Documentation provided to EPA and Ecology during the 1992 Revisions to Milestones Dispute outlined concerns that implementation of the aforementioned agreements would depreciate the quality and quantity of data available for input in the groundwater flow and transport modeling effort. The EPA and Ecology acknowledged these concerns but believed that a "bias-for-action" needed to be emphasized for the Phase II groundwater investigations at the 1100-EM-1 Operable Unit.

3.9.1 SPC Facility and DOE 300 Area Site Investigations

Various data derived from adjacent areas were considered in the 1100-EM-1 RI analyses. Groundwater level measurements taken in the 1100 Area were coordinated with measurements being taken for ongoing investigations at the SPC facility and within the Hanford 300 Area. During the last several rounds, groundwater level measurements were taken at the three areas on the same dates to make possible an accurate comparison of the data. SPC and 300 Area water level data were included in the 1100 Area analysis of groundwater flow direction beneath the Operable Unit; specifically, data were used in refining groundwater flow paths in the area encompassed by the groundwater model (see paragraph 6.2). Table 3-5 lists groundwater level measurements obtained from investigations performed in the 300 Area by WHC. Table 3-6 presents groundwater elevations measured at the SPC facility by Geraghty and Miller, Inc. Groundwater elevation for the 1100 Area wells were presented in table 2-6.

Analytical data from groundwater samples obtained from SPC wells were included in the development and analysis of the 1100 Area groundwater modeling effort. Groundwater sampled from monitoring wells on SPC property intercepting the plume contains dissolved ammonia, sulphate, fluoride, elevated beta activity, TCE, and nitrate. Chemical data obtained from samples collected at the SPC facility is presented in appendix F.

Aquifer pump testing was performed at both the SPC facility and within the 300 Area. Results of these efforts were used to confirm the validity of aquifer properties used in the 1100 Area groundwater model. Pump tests implemented in both the 300 Area and at the SPC facility are further described in paragraph 2.4.3.2.6, and in appendixes G and H.

3.9.2 1100-EM-1 Groundwater Investigations

As noted above, all analytical data for the Phase I RI have been published in DOE/RL-90-18 and WHC 1990. Phase II analytical data is presented in appendix E of this report. <u>All</u> the groundwater data were compared with operable unit-wide groundwater UTL's. Maximum values of all analytes exceeding these "background" values are presented in table 3-7.

This tabulated list of contaminants was further screened to remove: micronutrients (aluminum, barium, calcium, iron, magnesium, potassium, sodium, and zinc); contaminants detected at the analyte's Sample Quantitation Limit (methylene chloride, acetone, chloroform, toluene, C_{12} hydrocarbon, and diethylphthalate); or contaminants detected below current

Table 3–5.1100–EM–1 Operable Unit
300 Area Monitoring Well Groundwater Levels

Well ID	2/90	6/90	9/90	3/91	4/91	5/91	6/91	7/91	8/91	9/91	10/91	11/91	12/91	1/92	2/92	3/92	4/92	5/92	6/92	7/92	8/92	9/92
	DATES																					
	Groundwater Elevations (m)																					
399–1–3	104.63	105.67	103.99	104.91	105.45	105.73	105.53	104.78	104.61	104.00	104.28	104.29	104.58	104.25	104.01	104.16	104.44					
399–1–4	105.08	106.08	104.54	105.45	105.74	106.02	105.91	105.20	104.98	104.45	104.58	104.70	104.87	104.63	104.39	104.48	104.72					
399–1–5	104.77	105.79	104.13	105.14	105.50	105.79	105.58	104.86	104.72	104.22	104.37	104.42	104.67	104.35	104.10	104.19	104.50					
399–1–7	104.61	105.67	103.99	104.97	105.44	105.71	105.52	104.77	104.60	104.12	104.28	104.28	104.56	104.24	104.00	104.17	104.43					
399–1–8	NA	NA	NA	104.99	105.44	105.71	105.53	104.78	104.61	104.12	104.28	104.30	104.58	104.26	104.26	104.02	104.16					
399–1–10	104.77	105.80	104.15	105.20	105.73	106.03	105.79	104.92	104.90	NA	104.45	104.38	104.83	104.46	104.07	104.28	104.58					
399–1–11	104.92	105.92	104.40	105.32	105.61	105.89	105.70	105.01	104.79	104.30	104.42	104.50	104.74	104.46	104.21	104.30	104.59					
399–1–12	104.77	105.79	104.11	105.12	105.48	105.76	105.63	104.87	104.73	104.22	104.35	104.44	104.65	104.35	104.12	104.21	104.48					
399–1–13	104.79	105.80	104.14	105.13	105.47	105.75	105.66	104.90	104.76	104.24	104.37	104.48	104.64	104.38	104.16	104.24	104.48					
399–1–14	104.92	105.91	104.36	105.27	105.55	105.82	105.76	105.06	104.87	NA	104.46	104.58	104.74	104.50	104.28	104.33	104.57					
399–1–15	104.96	105.96	104.42	105.33	105.62	105.86	105.80	105.10	104.98	104.41	104.49	104.60	104.78	104.54	104.32	104.34	104.63					
399–1–16A	104.61	105.67	103.99	104.97	105.45	105.71	105.52	104.76	104.60	104.10	104.26	104.23	104.55	104.23	103.98	104.16	104.46					
399–1–17A	104.69	105.73	104.05	105.03	105.43	105.71	105.56	104.78	104.67	104.19	104.31	104.39	104.61	104.31	104.07	104.20	104.46					
399–1–19	104.73	105.78	104.09	105.09	105.47	105.75	105.55	NA	NA	NA	105.03	105.08	105.29	104.98	104.74	104.82	105.27					
399–2–1	104.58	105.59	103.93	104.77	105.45	105.74	105.50	104.57	104.61	104.04	104.21	104.16	104.52	104.23	103.94	104.12	104.44					
399–2–2	104.60	105.65	103.98	104.91	105.45	105.72	105.52	104.75	104.62	104.09	104.25	104.19	104.55	104.22	103.99	104.13	104.46					
399–2–3	104.59	105.65	103.97	104.89	105.45	105.71	105.50	104.73	104.58	104.08	104.25	104.17	104.51	104.20	104.05	104.12	104.44					
399–3–1	104.54	105.56	103.91	104.76	105.42	105.70	105.45	104.56	104.59	104.01	104.19	104.28	104.57	104.20	103.93	104.09	NA					
399–3–6	104.64	105.68	103.98	104.98	105.39	105.64	105.53	104.72	104.61	104.11	104.25	104.31	104.58	104.28	104.06	104.14	104.39					
399–3–7	104.62	105.66	103.97	105.26	105.40	105.66	105.50	104.71	104.59	104.10	104.24	104.29	104.59	104.25	104.04	104.13	104.42					
399–3–9	104.53	105.58	103.89	104.81	105.42	105.68	105.44	104.65	104.53	103.99	104.16	104.27	104.49	103.96	103.72	103.85	103.25					
399–3–10	104.51	105.54	103.86	104.77	105.40	105.67	105.40	104.62	104.51	103.96	104.13	104.27	104.57	104.19	103.95	104.08	104.38					
399–3–12	104.56	105.61	103.93	104.88	105.40	105.66	105.46	104.67	104.53	104.03	104.19	104.17	104.53	104.23	103.45	103.57	103.79					
399–4–1	104.49	105.53	103.87	104.79	105.37	105.63	105.37	104.59	104.46	103.98	104.30	104.14	104.50	104.16	103.73	103.85	104.19					
399–4–9	104.51	105.53	103.85	104.72	105.41	105.67	105.41	104.61	104.52	103.96	104.13	104.28	104.48	103.95	103.71	103.85	104.15					
399–4–10	104.50	105.51	103.83	104.67	105.40	105.66	105.38	104.58	104.51	103.89	104.09	104.27	104.43	104.18	103.91	104.07	104.38					
399–4–11	104.56	105.59	103.93	104.88	105.38	105.63	105.45	104.65	104.53	104.04	104.19	104.25	104.54	104.21	103.98	104.09	104.40					
399–5–1	104.68	105.66	104.03	104.97	105.36	105.60	105.51	104.74	104.67	104.15	104.28	104.40	104.53	104.62	104.11	104.15	104.39					
399–6–1	104.76	105.77	104.13	105.28	105.38	105.61	105.63	104.87	104.78	104.26	104.37	104.49	NA	103.84	103.66	103.66	103.82					
399–8–1	104.79	105.81	104.14	105.12	105.44	105.67	105.66	104.90	104.78	104.26	104.39	104.50	104.58	104.42	104.20	103.84	104.05					
399–8–2	104.96	105.93	104.43	105.22	105.42	105.64	105.78	105.14	104.99	104.56	104.55	104.64	104.59	104.65	104.46	104.46	103.89					
399–8–3	104.89	105.89	104.28	105.22	105.49	105.72	105.75	105.00	104.89	104.38	104.48	104.59	104.63	104.51	104.30	103.82	103.99					

BLANK – Measurements have been obtained but not yet entered into HEIS
NA – Measurements are not recorded in HEIS database

Table 3-6. 1100-EM-1 Operable Unit
Seimens Power Co. Monitoring Well Groundwater Levels

DATES

Groundwater Elevations (m)

Well ID	2/90	6/90	9/90	3/91	4/91	5/91	6/91	7/91	8/91	9/91	10/91	11/91	12/91	1/92	2/92	3/92	4/92	5/92	6/92	7/92	8/92	9/92
GM-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.35	108.31	108.27	108.20	108.15	108.10	108.12	108.18	108.189	108.204	
GM-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.34	108.31	108.28	108.23	108.18	108.13	108.13	108.18	108.216	108.219	
GM-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.30	108.26	108.23	108.19	108.14	108.09	108.08	108.128	107.866	108.171	
GM-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.22	108.20	108.17	108.12	108.08	108.03	108.02	108.067	108.116	108.116	
GM-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.16	108.17	108.14	108.10	108.05	108.00	107.99	108.052	108.094	108.091	
GM-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.18	108.18	108.15	108.10	108.06	108.01	107.99	108.043	108.079	108.082	
GM-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.12	108.14	108.11	108.07	108.03	107.97	107.96	108.006	108.04	108.049	
GM-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.10	108.12	108.09	108.05	108.02	107.97	107.95	107.991	108.03	108.037	
GM-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.10	108.09	108.06	108.03	107.99	107.94	107.92	107.954	107.994	108.003	
GM-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	108.09	108.07	108.05	108.01	107.98	107.92	107.90	107.665	107.707	107.713	
GM-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	107.98	108.00	107.98	107.94	107.91	107.85	107.83	107.869	107.607	107.918	
GM-12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	107.89	107.90	107.88	107.83	107.80	107.75	107.72	107.765	107.805	107.805	
TW-1	NA	NA	107.92	NA	NA	NA	NA	107.96	108.04	NA	NA	108.20	108.21	108.19	108.14	108.10	108.05	108.04	108.085	108.113	108.128	
TW-2	NA	NA	107.91	NA	NA	NA	NA	107.96	108.04	NA	NA	108.20	108.21	108.18	108.13	108.09	108.04	108.03	108.079	108.11	108.122	
TW-3	NA	NA	107.94	NA	NA	NA	NA	107.99	108.11	NA	NA	108.27	108.24	108.21	108.16	108.11	108.06	108.03	108.11	108.131	108.146	
TW-4	NA	NA	107.96	NA	NA	NA	NA	108.00	108.09	NA	NA	108.24	108.25	108.22	108.16	108.12	108.07	108.06	108.116	108.146	108.155	
TW-5	NA	NA	107.96	NA	NA	NA	NA	108.01	108.10	NA	NA	108.25	108.26	108.23	108.17	108.12	108.07	108.07	108.128	108.152	108.162	
TW-6	NA	NA	107.97	NA	NA	NA	NA	108.03	108.12	NA	NA	108.27	108.27	108.24	108.18	108.13	108.08	108.08	108.14	108.158	108.174	
TW-7	NA	NA	107.98	NA	NA	NA	NA	108.04	108.17	NA	NA	108.33	108.29	108.25	108.20	108.14	108.09	108.09	108.152	108.177	108.189	
TW-9	NA	NA	107.91	NA	NA	NA	NA	107.95	108.11	NA	NA	108.18	108.20	108.17	108.12	108.08	108.04	107.99	108.049	108.091	108.116	
TW-11	NA	NA	107.99	NA	NA	NA	NA	108.03	108.03	NA	NA	108.28	108.28	108.25	108.19	108.14	108.09	108.09	108.149	108.174	108.183	
TW-12	NA	NA	108.00	NA	NA	NA	NA	108.04	NA	NA	NA	108.29	108.29	108.25	108.20	108.15	108.09	108.09	108.152	108.183	108.189	
TW-13	NA	NA	108.00	NA	NA	NA	NA	108.07	108.17	NA	NA	108.29	108.31	108.27	108.21	108.15	108.10	108.12	108.158	108.192	108.204	
TW-14	NA	NA	107.84	NA	NA	NA	NA	107.83	108.13	NA	NA	108.10	108.08	108.06	108.02	107.98	107.93	107.91	107.948	107.997	108.003	
TW-15	NA	NA	108.10	NA	NA	NA	NA	107.82	108.16	NA	NA	108.06	108.08	108.05	108.02	107.98	107.93	107.91	107.945	107.973	107.994	
TW-16	NA	NA	108.16	NA	NA	NA	NA	107.88	107.98	NA	NA	108.12	108.13	108.12	108.08	107.83	107.99	107.97	107.942	107.68	108.052	
TW-19	NA	NA	107.93	NA	NA	NA	NA	107.97	108.00	NA	NA	108.21	108.22	108.19	108.15	108.10	108.05	108.04	108.091	108.122	108.128	
TW-20	NA	NA	107.94	NA	NA	NA	NA	108.00	107.98	NA	NA	108.23	108.24	108.21	108.16	108.12	108.06	108.05	108.104	108.14	108.149	
TW-21	NA	NA	107.96	NA	NA	NA	NA	108.01	NA	NA	NA	108.27	108.27	108.24	108.18	108.12	108.09	108.08	108.134	108.165	108.171	
TW-22	NA	NA	107.99	NA	NA	NA	NA	108.04	NA	NA	NA	108.28	108.28	108.23	108.18	108.12	108.07	108.09	108.146	108.158	108.113	
TW-23	NA	NA	108.02	NA	NA	NA	NA	108.07	108.06	NA	NA	108.35	108.33	108.29	108.24	108.20	108.14	108.11	108.189	108.119	108.259	
TW-24	NA	NA	108.00	NA	NA	NA	NA	108.05	108.08	NA	NA	108.31	108.30	108.27	108.22	108.17	108.13	108.08	108.158	NA	NA	
TW-25	NA	NA	108.01	NA	NA	NA	NA	108.08	108.12	NA	NA	108.30	108.32	108.29	108.25	108.21	108.17	108.12	108.177	108.219	108.268	
TW-26	NA	NA	107.91	NA	NA	NA	NA	107.96	108.13	NA	NA	108.19	108.20	108.18	108.13	108.09	108.04	107.99	108.034	108.061	108.116	

BLANK – Measurements have been obtained but not yet entered into HEIS
NA – Measurements are not recorded in HEIS database

Table 3-7. Maximum Concentration of Groundwater Analytes Observed Exceeding Background or MCL's for Metals, Wet Chemistry, Volatile Organics, Semivolatile Organics, Pesticides, and Radionuclides for Sampling Rounds 1-9.

Analytes	MCL Level	UTL's	Maximum Concentration Observed
Metals (ppb)			
Aluminum	50-200 [a]	152	1350
Barium	1000	60.5	132 B [f]
Calcium	NA [i]	74600	197000
Chromium	100 [b]	7.8	57.5
Copper	1300	5.22 [h]	71.9
Iron	300 [a]	820	2050
Lead	50 [c]	13.7	25.3
Magnesium	NA	20200	42100
Manganese	NA	390	352
Nickel	100 [d]	15	140 [j]
Silver	50	4	11.7
Potassium	NA	7140	13900
Sodium	NA	29500	56900
Zinc	NA	8.3	223
Wet Chemistry (ppm)			
Ammonia	NA	0.15	.087
Fluoride (F)	4 [b]	0.5	3.7
Chloride (Cl)	250 [a]	22.1	110
Phosphate (PO_4-P)	NA	1	1.9
Sulfate (SO_4)	255 [a]	42.5	89.6
Nitrate (as N)	10	12.3	**217**

Table 3-7. Maximum Concentration of Groundwater Analytes Observed Exceeding Background or MCL's for Metals, Wet Chemistry, Volatile Organics, Semivolatile Organics, Pesticides, and Radionuclides for Sampling Rounds 1-9.

Analytes	MCL Level	UTL's	Maximum Concentration Observed
Votatile Organics, Semivolatile Organics, and Pesticides (ppb)			
Methylene Choride	5 [d]	1	13
Acetone	NA	10	31
Chloroform	100	1	5
1,1,1-Trichloroethane	200 [b]	1.2	3
Trichloroethene	5 [b]	1	104 D [g]
Tetrachloroethene	5 [b]	1	4 J
Toluene	2000 [d]	1	2 J
C_{12} Hydrocarbon	NA	NA	100 J [e]
Diethylphalate	NA	10	34
Radionuclides (pCi/L)			
Gross Alpha	15 [b]	8.4	11 + 5
Gross Beta	50 [a]	18	87 7
Radium	20	1.7 [h]	2.36

[a] National Secondary Drinking Water Regulations - Secondary Maximum Contaminant Levels.
[b] National Revised Primary Drinking Water Regulations - Maximum Contaminant Levels (MCL's).
[c] Primary Drinking Water Regulations - Maximum Contaminant Levels (effective through 7 Dec 92).
[d] Proposed National Primary Drinking Water Regulations - Maximum Contaminant Levels.
[e] J= estimated value.
f B means analyte was also found in the blank, the concentration reported is uncertain.
[g] D means the concentration was determined at a secondary dilution.
[h] Parameter was never detected in the respective background samples; therefore, the highest reported respective background SQL is substituted as a surrogate UTL.
[i] NA = not available or not applicable.
[j] Issues not yet revolved for suspicious values: additional data is being obtained for further evaluation.

MCL's (chromium; copper; lead; silver; 1,1,1-trichloroethane; tetrachloroethene; radium; gross alpha; chloride; and sulfate).

Ammonia was not considered further because of the low concentrations at which it was detected, and because it degrades to nitrate. Nitrate does have an MCL and was considered in subsequent analyses for 1100-EM-1 contaminants through the risk assessment phase of the investigation.

Nickel was identified just exceeding a "proposed" MCL of 100 μg/L at two wells during the RI. These concentrations over "proposed MCL" were not consistently found throughout the sampling, but only in the last round of samples. A total of six rounds of ground water data had been collected. In addition, elevated nickel concentrations were not identified in soil samples taken from either of these two wells. A Hazard Quotient(HQ) of 0.2 was calculated for the maximum concentration of nickel (140 μg/L). A HQ of less than 1.0 indicates the possibility of systemic toxic effects is small. There was no slope factor for ingestion of nickel to calculate the carcinogenic risk. This element was not one of the chemicals included in the groundwater portion of the risk assessment for this RI/FS. Future groundwater samples will continue to monitor the levels of nickel in these wells.

An MCL for specific beta activity has not been developed. However, compliance with individual MCL's for beta emitters may be assumed, without further analysis, if the average maximum contaminant levels are intended to produce an annual dose equivalent to the total body or any internal organ less than 4 millirem/year. Specifically, if the average annual concentration of gross beta activity is less than 50 pCi/L. Since the gross beta activity exceeded this concentration, specific analyses of the potential beta-contributing radionuclides were conducted (40 CFR, parts 141, 142, and 143).

Technetium-99 (Tc-99) appears to account for most, if not all, of the elevated beta activity. No other significant contributors to the total beta activity have been detected (Prentice *et. al.*, 1992). Other analyses were made to search for the presence of tritium and strontium-90 in the groundwater using liquid scintillation and gamma spectrometry analysis techniques. Neither analyte was detected.

Tc-99 is a fission product derived mainly from the recycling of nuclear fuels. It is very persistent in the environment, having a half-life of 2.1E+05 years; however, it poses a relatively small internal health hazard. This minimal health hazard is evidenced by the high proposed MCL for Tc-99 (3.8E+03 pCi/L) and its relatively small ingestion slope factor (1.3E-12/pCi). The average Tc-99 concentration measured in HRL/SPC groundwater samples was 120 pCi/L. Since this concentration is well below proposed MCL's, the gross beta activity was eliminated from further evaluation in the risk assessment process.

After the above screening process, analytes remaining, *i.e.*, TCE and nitrate, are evaluated as contaminants of potential concern for 1100-EM-1 Operable Unit groundwater. These two contaminants are consistent with the list of contaminants of potential concern to be considered as directed by EPA (see section 5.0).

A limited sampling and analysis program was implemented to investigate the possibility of VOC contaminants emanating from the 1100-2 subunit, the Paint and Solvent Pit, entering the groundwater. Compounds detected in groundwater samples collected from wells MW-4, MW-5, MW-6, and MW-18 included chloroform (1.0 to 5.0 μg/L), diethylphthalate (19.0 μg/L), acetone (14.0 μg/L), TCA (2.0 to 4.0 μg/L), and tetrachloroethene (1.0 μg/L). The first three compounds were detected sporadically at very low concentrations. There are no published MCL values for these compounds. The MCL's for TCA and tetrachloroethene are 200 μg/L and 5 μg/L, respectively. Both were detected sporadically at concentrations below the MCL values. The results of the limited sampling and analysis program do not support the 1100-2 subunit as a source of groundwater VOC contamination at levels of concern.

3.10 SUMMARY OF SITE INVESTIGATIONS

Site investigations of the 1100-EM-1 Operable Unit included radiological surveys, geophysical surveys, soil-gas surveys, intrusive trenching activities to explore subsurface conditions, surface and subsurface soil sampling and laboratory analyses, groundwater level monitoring, and groundwater sampling and laboratory analyses. Maximum values for all analytes at each subunit are summarized for surface and subsurface soils in tables 3-1 and 3-2. These maximum values are compared with site-wide UTL's or background. The tables were further screened to remove essential micronutrients. For soils collected at each subunit, the maximum values of analytes detected at levels exceeding background are presented in table 3-4. These remaining soil contaminants are used for risk-based pre-screening to develop contaminants of potential concern (COPC) in section 4.

Analytical results of Phase II groundwater investigations are presented in appendix E. Additional chemical data from earlier phases of the RI are presented in DOE/RL-90-18 and WHC 1990. Table 3-7 lists groundwater contaminants measured at concentrations above MCL's or site background. Groundwater contaminants were further screened to remove micronutrients and those analytes occurring at concentrations below published regulatory criteria. Anomalous measurements, including those confirmed by subsequent measurements to be below regulatory criteria, were also screened at this stage. TCE and nitrate remain as the contaminants of potential concern for the groundwater at and near the HRL subunit. Groundwater contamination is not an issue at the remaining six subunits of the 1100-EM-1 Operable Unit.

The distribution of the contaminants of potential concern for both soil and groundwater will be discussed in additional detail in section 4.0.

4.0 NATURE AND EXTENT OF CONTAMINATION

Section 4.0 presents the nature and extent of contamination detected within the 1100-EM-1 Operable Unit. The focus is on the significant contaminants and their distribution throughout the Operable Unit. All analytes detected in concentrations exceeding background levels were identified in section 3.0. This extensive list was further screened to include only those contaminants exceeding published criteria, or where substantiated anomalies were measured (tables 3-6 and 3-7). In this section, the screened lists are reviewed and risk-based screening criteria are applied. Contaminants remaining after the risk-based evaluation will constitute the contaminants of concern for the Operable Unit. Further development and discussion of the risk-based screening and risk assessment process are presented in section 5.0 and appendix K.

Groundwater contaminants are limited to trichloroethene and nitrate contaminated plumes detected beneath SPC property and beneath the HRL subunit. All other contaminants detected during the Phase I and Phase II groundwater sampling rounds were eliminated from further consideration as described in the previous section. Groundwater contamination will not be discussed for subunits other than HRL.

Analytical results from surface soil samples recovered within the Operable Unit confirm the presence of surface soil contamination in concentrations above UTL's. Some areas are characterized by a single soil sample and others by more than one soil sample. The distribution of surface soil contamination present in concentrations above UTL's are illustrated in figures 4-1 through 4-24. All maps were developed by locating soil sampling sites having elevated analyte values, estimating the horizontal extent of contamination based on surface topographic features, and by postulating the most plausible explanation for the existence of the concentration at each sampling site. For example, if only a single soil sample was collected from the floor of a surface depression, then the sample was assumed to be representative of the total area of the depression floor. A single positive soil analysis from the base of a depression where more than a single soil sample was obtained was interpreted as being representative of the depression base immediately adjacent to the sampling location, possibly indicating the presence of a localized low within the depression. The mode of contaminant accumulation was interpreted as runoff flowing into the depression and depositing contaminated soil, by spills or dumping incidents or, alternatively, wind deposition of contaminated sediments. Contaminant concentrations located on flat terrain were illustrated as having a lateral extent large enough to be obvious; the mode of contaminant accumulation, in flat areas, not being as easily theorized as elevated concentrations present within surface depressions. Surface soil contamination maps are not to be construed as absolutes, but only as indications of the general distribution of the contaminants within the boundaries of each subunit.

4.1 BATTERY ACID PIT - 1100-1

Elevated concentrations of contaminants detected within the surface and subsurface soils at the 1100-1, Battery Acid Pit subunit are listed in paragraph 3.1.1. Results of preliminary risk-based screening for the remaining soil contaminants present at this subunit are summarized in table 4-1. The only COPC's at the 1100-1, Battery Acid Pit subunit are vanadium, arsenic, and nickel. Vanadium and arsenic were observed in a single soil sample, A1004S, obtained from the depth interval of 1.6 to 1.9 m (5.3 to 6.1 ft) below the ground surface at borehole BAP-1 (see figure 3-1). Neither contaminant was detected in surface soil samples. Nickel was observed in a single soil sample at the ground surface at the location of borehole BAP-1. The remaining contaminants (such as copper, mercury, and zinc) pose no known human health or environmental risks at the measured concentrations. Lead concentration is below published cleanup criteria.

4.2 PAINT AND SOLVENT PIT - 1100-2

Contaminants detected in soil samples at the 1100-2, Paint and Solvent Pit subunit are listed in paragraph 3.2.1. As insufficient data are available to ascertain speciation, chromium is conservatively assumed to be in the hexavalent (most toxic) state for the purposes of this report. Results of preliminary risk-based screening for soil contaminants at the 1100-2, Paint and Solvent Pit subunit are summarized in table 4-2. The only resultant COPC's for the 1100-2 subunit are chromium and manganese. Elevated chromium is found within only a single surface soil sample obtained immediately prior to the drilling of borehole DP-9 (figure 4-1). Manganese is found within only a single subsurface soil sample from borehole DP-6, at a depth interval of 1.9 to 2.4 m (6.3 to 7.9 ft). The remaining contaminants (copper, thallium, zinc, chlorobenzene, DDT, PCE, and TCE) pose no known human health or environmental risks at the measured concentrations. Lead levels are below the published cleanup criteria.

4.3 ANTIFREEZE AND DEGREASER PIT - 1100-3

Soil contaminants detected at concentrations above background levels at the 1100-3, Antifreeze and Degreaser Pit subunit are listed in paragraph 3.3.1. Table 4-3 summarizes the results of the preliminary risk-based screening for the subunit. Chromium exceeds the screening criteria and is thus regarded as the only COPC at the 1100-3 subunit.

Chromium was encountered in concentrations exceeding background levels at only one surface location in the extreme northeast portion of the Antifreeze and Degreaser Pit (figure 4-2). This substance was not encountered at elevated levels in the subsurface stratum of the 1100-3 subunit soils. Manganese was detected in elevated concentrations in four subsurface samples obtained from borehole DP-8, spanning a depth interval from 3.3 m to 8.1 m (10.8 ft to 26.4 ft). Other contaminants (cobalt, copper, and zinc) occur at levels that pose no known substantive threat to the environment or public health. Lead occurs at levels well below published cleanup criteria.

4.4 ANTIFREEZE TANK SITE - 1100-4

Elevated contaminant parameters detected in the subsurface soils at and near the 1100-4, Antifreeze Tank Site subunit are listed in paragraph 3.4.1. Aluminum and

Table 4-1. Preliminary Risk-Based Screening for Soil Contaminants at the Battery Acid Pit (1100-1) Subunit.

Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Arsenic	3.2	3.0E-04[a]	2.4	--	--	1.7E+00[e]	0.038	5.0E+01[a,b]	1.1	--
Copper	37.9	4.0E-02[f]	320	--	--	--	--	--	--	--
Lead	266	ND	--	ND	--	ND	--	ND	--	500-1,000[d]
Mercury	0.39	3.0E-04[b]	2.4	8.5E-05[b]	280	--	--	--	--	--
Nickel	20.9	2.0E-02[a]	160	--	--	--	--	8.4E-01[a]	19	--
Vanadium	118	7.0E-03[b]	56	--	--	--	--	--	--	--
Zinc	100	2.0E-01[b]	1,600	--	--	--	--	--	--	--

[a]Integrated Risk Information System (IRIS, EPA 1992a)
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992b)
[c]Based on 30% absorption of inhaled arsenic (EPA 1992b)
[d]EPA 1989b
[e]Surrogate based on proposed arsenic unit risk of 5E-05 μg/L (EPA 1991).
[f]EPA Region-10 (see Appendix A)

-- Indicates not available

ND Not Determined

Note: Shaded areas indicate screening criterion exceeded

9 3 1 2 9 3 3 0 2 3 1

Table 4-2. Preliminary Risk-Based Screening for Soil Contaminants at the Paint and Solvent Pit (1100-2) Subunit.

Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Chromium	16.8	5.0E-03[a]	40	--	--	--	--	4.1E+01[a]	0.40	--
Copper	24.4	4.0E-02	320	--	--	--	--	--	--	--
Lead	94.6	ND	--	ND	--	ND	--	ND	--	500-1000[c]
Manganese	366	1.0E-01[a]	800	1.1E-04[a]	350	--	--	--	--	--
Thallium	0.48	7.0E-05[b]	0.56	--	--	--	--	--	--	--
Zinc	56.6	2.0E-01[b]	1,600	--	--	--	--	--	--	--
Chlorobenzene	0.006	2.0E-02[a]	160	5E-03[b]	16,000	--	--	--	--	--
DDT	0.16	5.0E-04[a]	4.0	--	--	3.4E-01[a]	0.19	3.4E-01[a]	48	--
Tetrachloroethene	0.035	1.0E-02[a]	80	--	--	5.2E-02[d]	1.2	2E-03[d]	8,200	--
Trichloroethene	0.006	--	--	--	--	1.1E-02	5.8	6.0E-03	2,700	--

[a]Integrated Risk Information System (IRIS, EPA 1992a)
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992b)
[c]EPA 1989b
[d]EPA-Region 10 (see Appendix A)
-- Indicates not available
ND Not Determined
Note: Shaded areas indicate screening criterion exceeded

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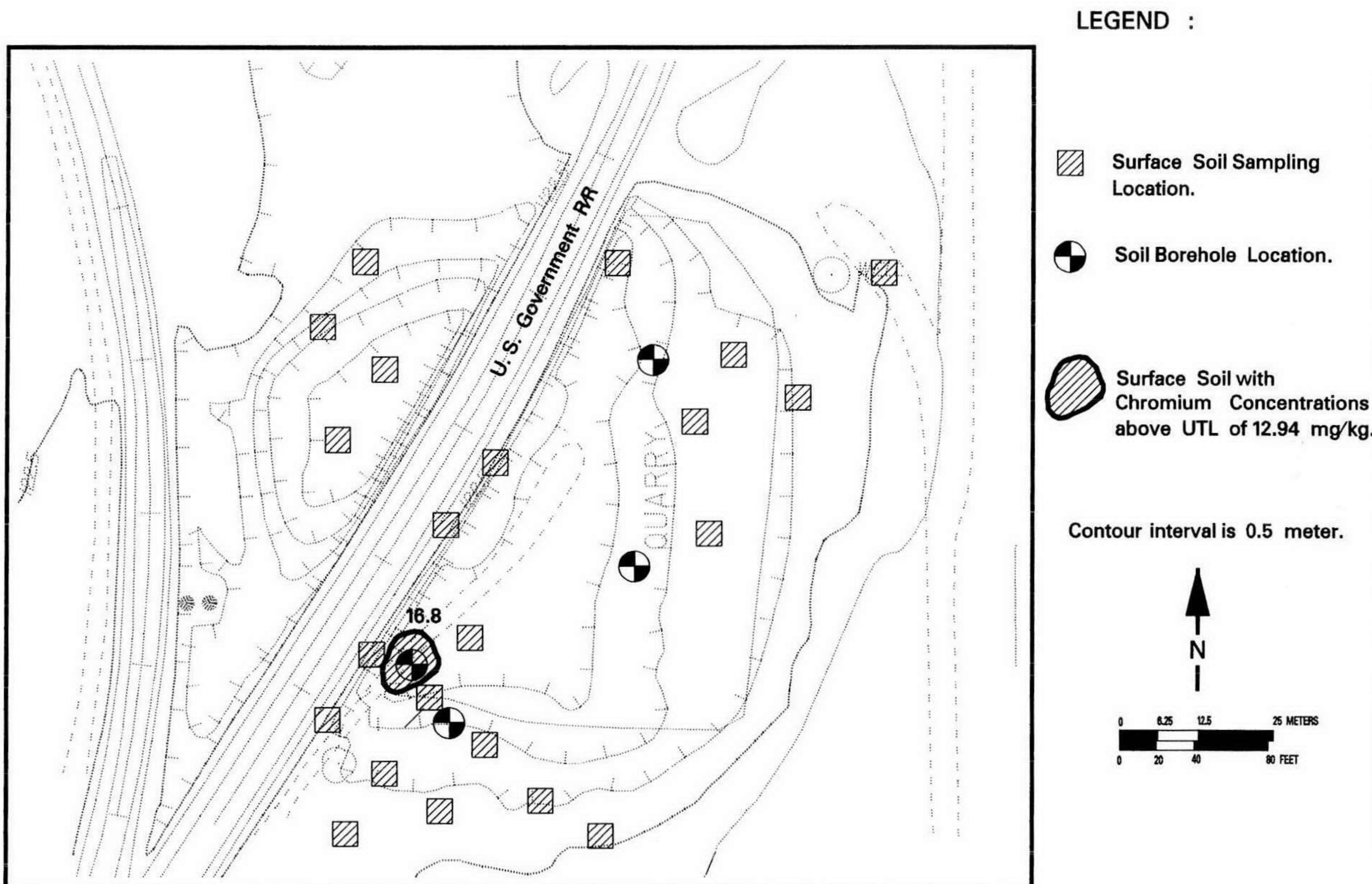

1100–2, Paint and Solvent Pit – Chromium Distribution in Surface Soils.

Figure 4–1

Table 4-3. Preliminary Risk-Based Screening for Soil Contaminants at the Antifreeze and Degreaser Pit (1100-3) Subunit.

Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Chromium	14	5.0E-03[a]	40	--	--	--	--	4.1E+01[a]	.40	--
Cobalt	17.8	6.0E-02[c]	480	--	--	--	--	--	--	--
Copper	31.7	4.0E-02[f]	320	--	--	--	--	--	--	--
Lead	26.4	ND	--	ND	--	ND	--	ND	--	500-1,000[d]
Manganese	436	1.0E-01[a]	800	1.1E-04[a]	350	--	--	--	--	--
Zinc	60	2.0E-01[b]	1,600	--	--	--	--	--	--	--

[a] Integrated Risk Information System (IRIS, EPA 1992a)
[b] Health Effects Assessment Summary Tables (HEAST, EPA 1992b)
[c] Based on 30% absorption of inhaled arsenic (EPA 1992b)
[d] EPA 1989b
[e] Surrogate based on proposed arsenic unit risk of 5E-05 μg/L (EPA 1991)
[f] EPA Region-10 (see Appendix A)

-- Indicates not available
ND Not Determined
Note: Shaded areas indicate screening criterion exceeded

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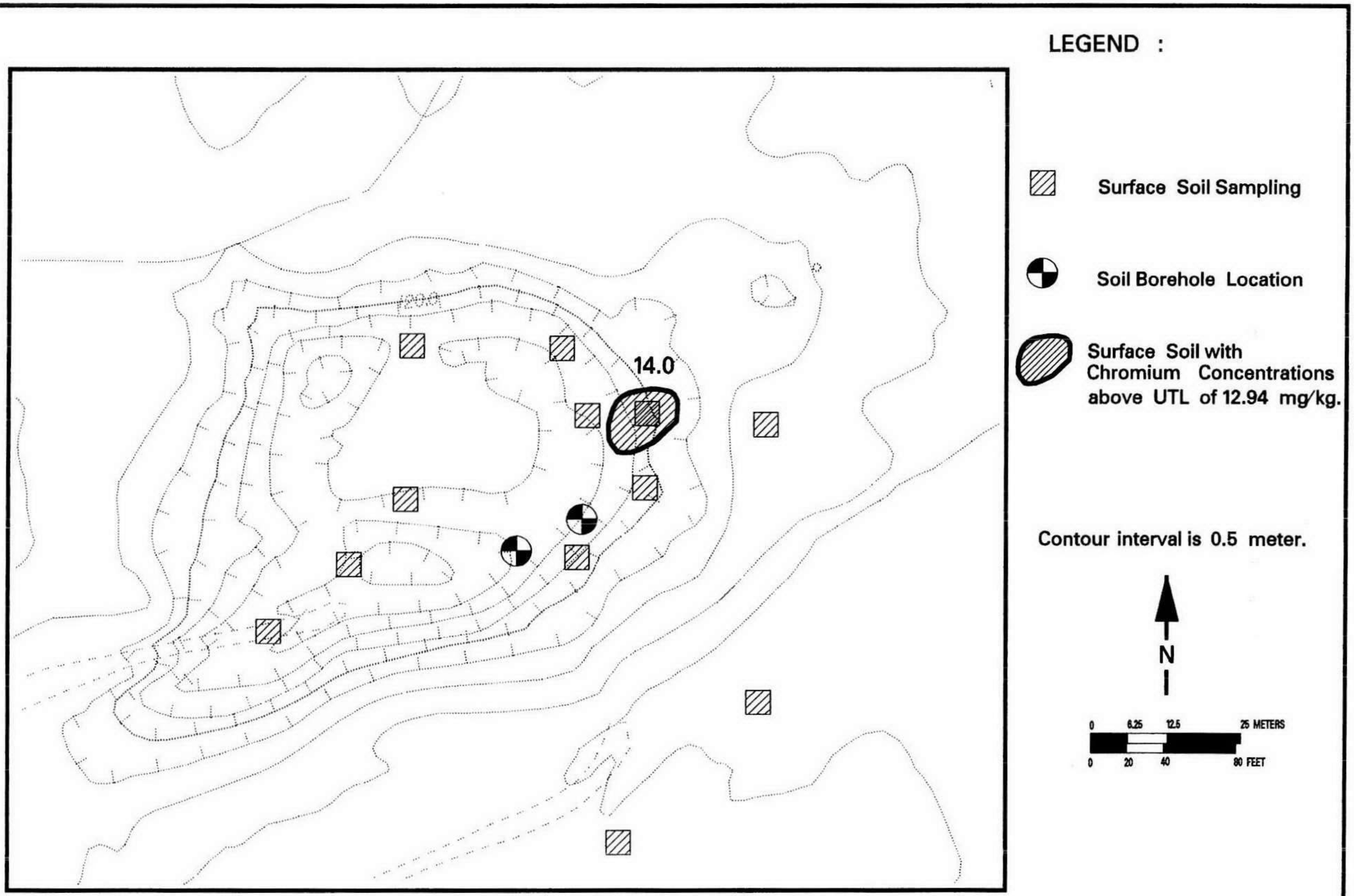


1100–3, Antifreeze and Degreaser Pit – Chromium Distribution in Surface Soils.

Figure 4–2

potassium, the only two contaminants associated with the actual location of the former antifreeze disposal tank, were eliminated from further consideration for reasons previously stated in section 4.0. No organic compounds were detected at elevated levels within this subunit. The remaining parameters were detected at elevated concentrations only at the location of a nearby groundwater monitoring well, MW-3, to be discussed in the following paragraph.

Preliminary risk-based screening of contaminants detected near the Antifreeze Tank Site in soil samples obtained during the installation of monitoring well MW-3 (see figure 3-1) indicates that arsenic and beryllium are the only parameters that exceed screening criteria (table 4-4). Arsenic was encountered at an elevated concentration in only a single sample obtained from below the water table, approximately 15 m (50 ft) below the ground surface. Beryllium was detected at elevated concentrations throughout the soil column penetrated during the installation of well MW-3. Concentrations detected varied from a low of 0.51 milligrams (mg)/kg to a high of 0.93 mg/kg. The maximum concentration was detected at a depth of approximately 7.9 m (26 ft) below the ground surface. There was no apparent pattern to the distribution of beryllium within the soil column.

Other contaminants (copper, silver, thallium, and zinc) are present at levels posing no known substantive risk to public health or the environment. Lead is measured at levels below cleanup criteria.

4.5 DISCOLORED SOIL SITE - UN-1100-6

Inorganic and organic contaminants present in the surface soils of the UN-1100-6, Discolored Soil Site subunit are listed in paragraph 3.5.1. Table 4-5 summarizes the preliminary risk-based screening for the UN-1100-6 subunit.

Because there are insufficient data to develop an RfD for di-n-octyl phthalate, and the substance is not a known carcinogen, this compound is combined and evaluated with the carcinogen, BEHP. Insignificant concentrations of di-n-octyl phthalate, as compared with BEHP, provide further justification for combining these two substances for the purposes of further evaluation.

The COPC for the UN-1100-6, Discolored Soil Site subunit - BEHP, chlordane, and heptachlor - were each encountered in several samples. Figure 4-3 shows the areal distribution of BEHP at the subunit. Figures 4-4 and 4-5 illustrate the distribution of alpha- and gamma-chlordane within the UN-1100-6 subunit. Figure 4-6 presents the areal extent of heptachlor contamination at the Discolored Soil Site. All surface contamination is limited to the eastern end of the depression, coincident with the actual area of stained soil. The aerial extent of contamination indicated on the figures was based on soil analytical analyses and a field examination of the site. Uncertainties in the extent of contamination in a westerly direction are addressed in section 7, where the area to be remediated is extended westward to include the nearest sampling point where a non-detect reading was obtained (see

Table 4-4. Preliminary Risk-Based Screening for Soil Contaminants at the Antifreeze Tank Site (1100-4) Subunit.

Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Arsenic	5.8	3.0E-04[a]	2.4	--	--	1.7E+00[e]	0.038	5.0E+01[a]	1.1[c]	--
Beryllium	0.93	5.0E-03[a]	40	--	--	4.3E+00[a]	0.015	8.4E+00[a]	1.9	--
Copper	19.8	4.0E-02[f]	320	--	--	--	--	--	--	--
Lead	5.7	ND	--	ND	--	ND	--	ND	--	500-1000[d]
Silver	2	5.0E-03[a]	40	--	--	--	--	--	--	--
Thallium	0.48	7.0E-05[b]	0.56	--	--	--	--	--	--	--
Zinc	63.8	2.0E-01[b]	1,600	--	--	--	--	--	--	--

[a] Integrated Risk Information System (IRIS, EPA 1992a)
[b] Health Effects Assessment Summary Tables (HEAST, EPA 1992b)
[c] Based on 30% absorption of inhaled arsenic (EPA 1992b)
[d] EPA 1989b
[e] Surrogate based on proposed arsenic unit of risk of 5E-05 μm/L (EPA 1991)
[f] EPA Region-10 (see Appendix A)
-- Indicates not available
ND Not Determined
Note: Shaded area indicate screening criterion exceeded

Table 4-5. Preliminary Risk-Based Screening for Soil Contaminants at the Discolored Soil Site (UN-1100-6) Subunit.

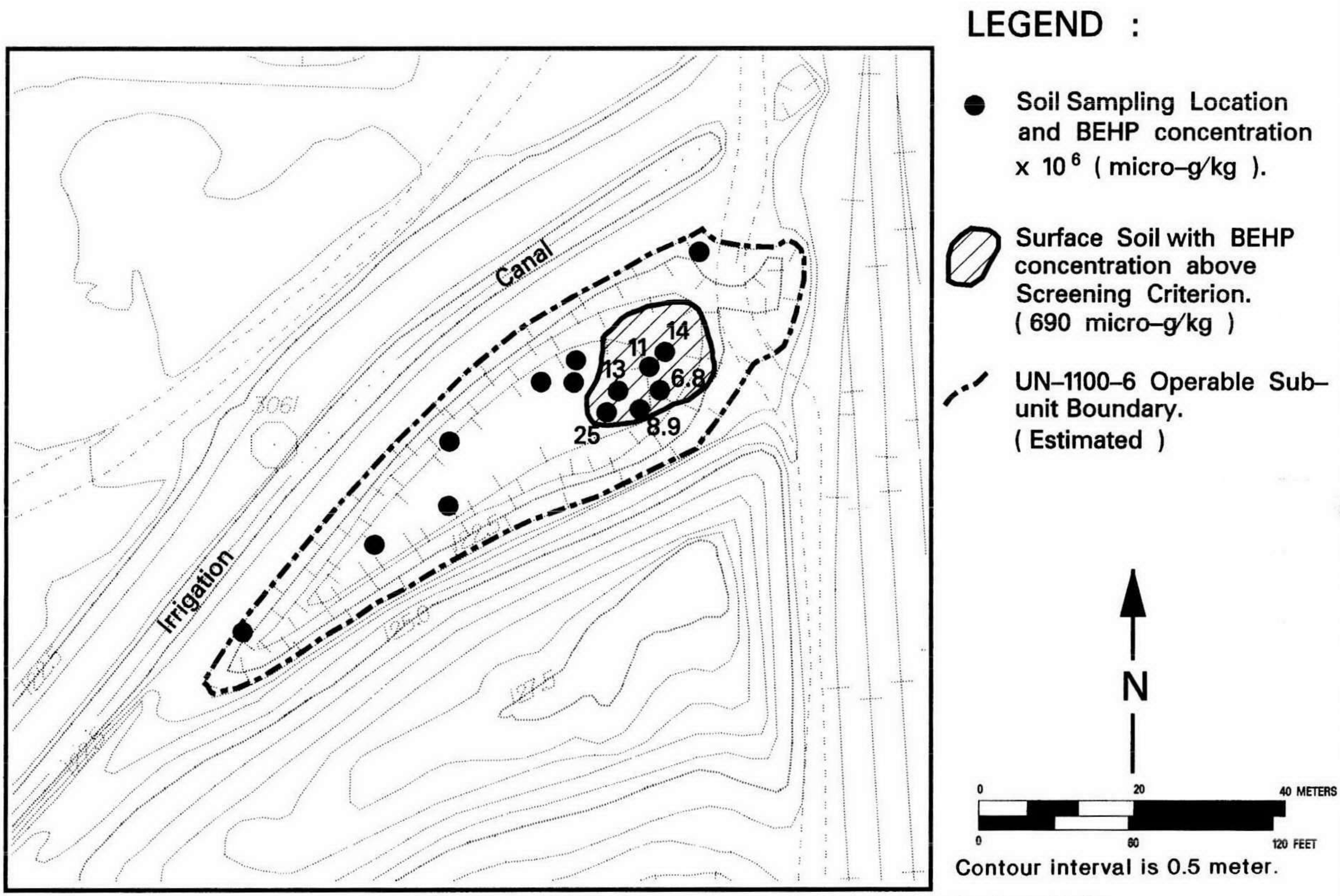
Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF (mg/kg-d)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF (mg/kg-d)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Lead	22.1	ND	--	ND	--	ND	--	ND	--	500-1,000[c]
Zinc	111	2.0E-01[b]	1,600	--	--	--	--	--	--	--
BEHP	25,000	2.0E-02[a]	160	--	--	1.4E-02[a]	4.5	1.4E-02[d]	1,200	--
Chlordane	1.86	6.0E-05[a]	0.48	--	--	1.3E+00[a]	0.049	1.3E+00[a]	13	--
DDT	0.17	5.0E-04[a]	4.0	--	--	3.4E-01[a]	0.19	3.4E-01[a]	48	--
Heptachlor	0.065	5.0E-04[a]	4.0	--	--	4.5E+00[a]	0.014	4.5E+00[a]	3.6	--
2-hexanone	0.053	5.0E-02[f]	400	9.0E-02[f]	290,000	-	--	--	--	--
1,1,1-trichloroethane	0.035	9.0E-02	720	3E-01	960,000	-	--	--	--	--

[a]Integrated Risk Information System (IRIS, EPA 1992a)
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992b)
[c]EPA 1989b
[d]Surrogate inhalation SF assumed to equal BEHP oral SF
[e]Surrogate based on proposed arsenic unit risk of 5E-05 μg/L (EPA 1991)
[f]Surrogate based on 2-butanone (HEAST, EPA 1992b)

-- Indicates not available

ND Not Determined

Note: Shaded areas indicate screening criterion exceeded



UN–1100–6, Discolored Soil Site – BEHP Distribution in Surface Soils at Concentrations above a UTL of 690 micro–g/kg.

Figure 4–3

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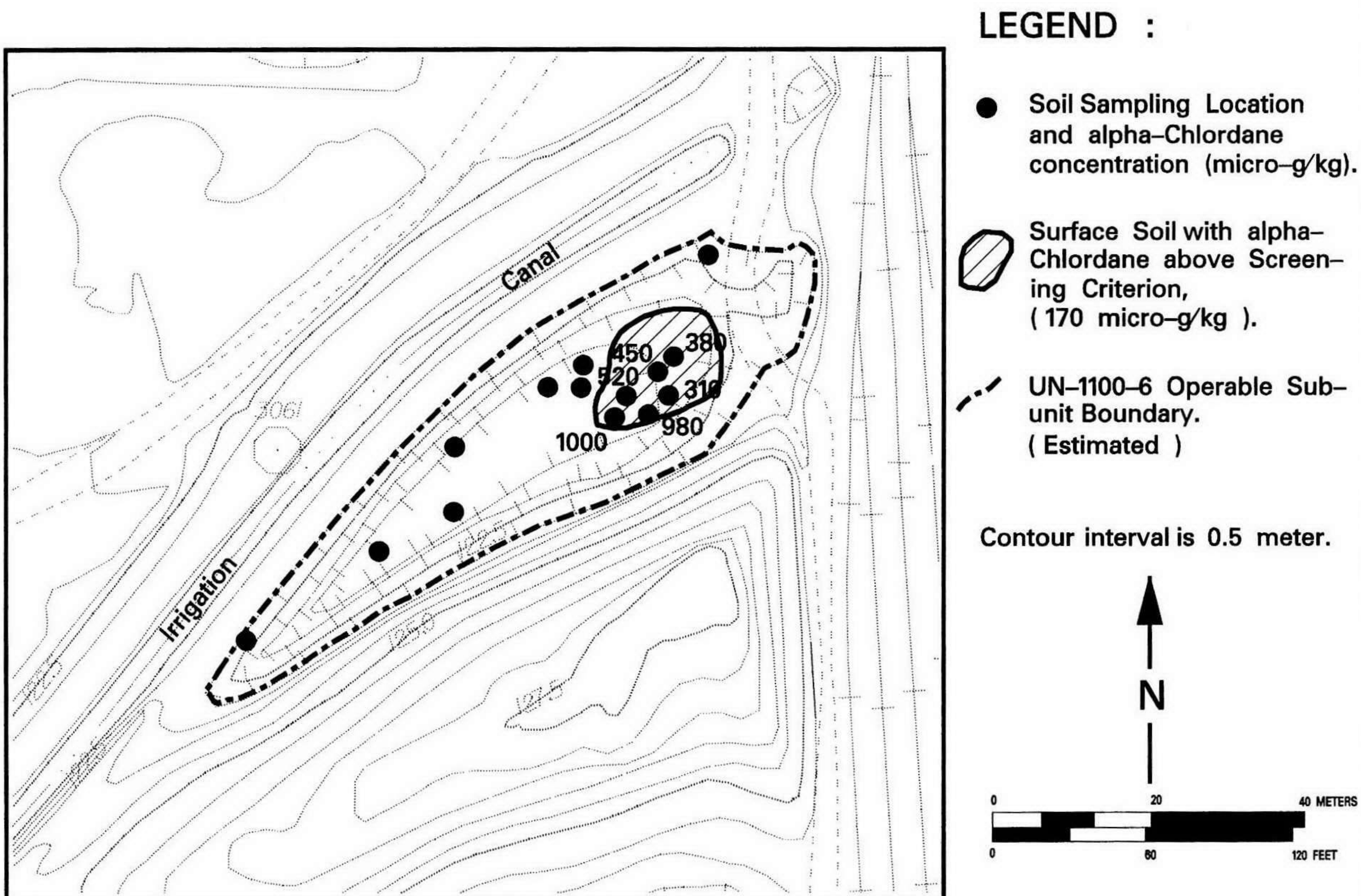

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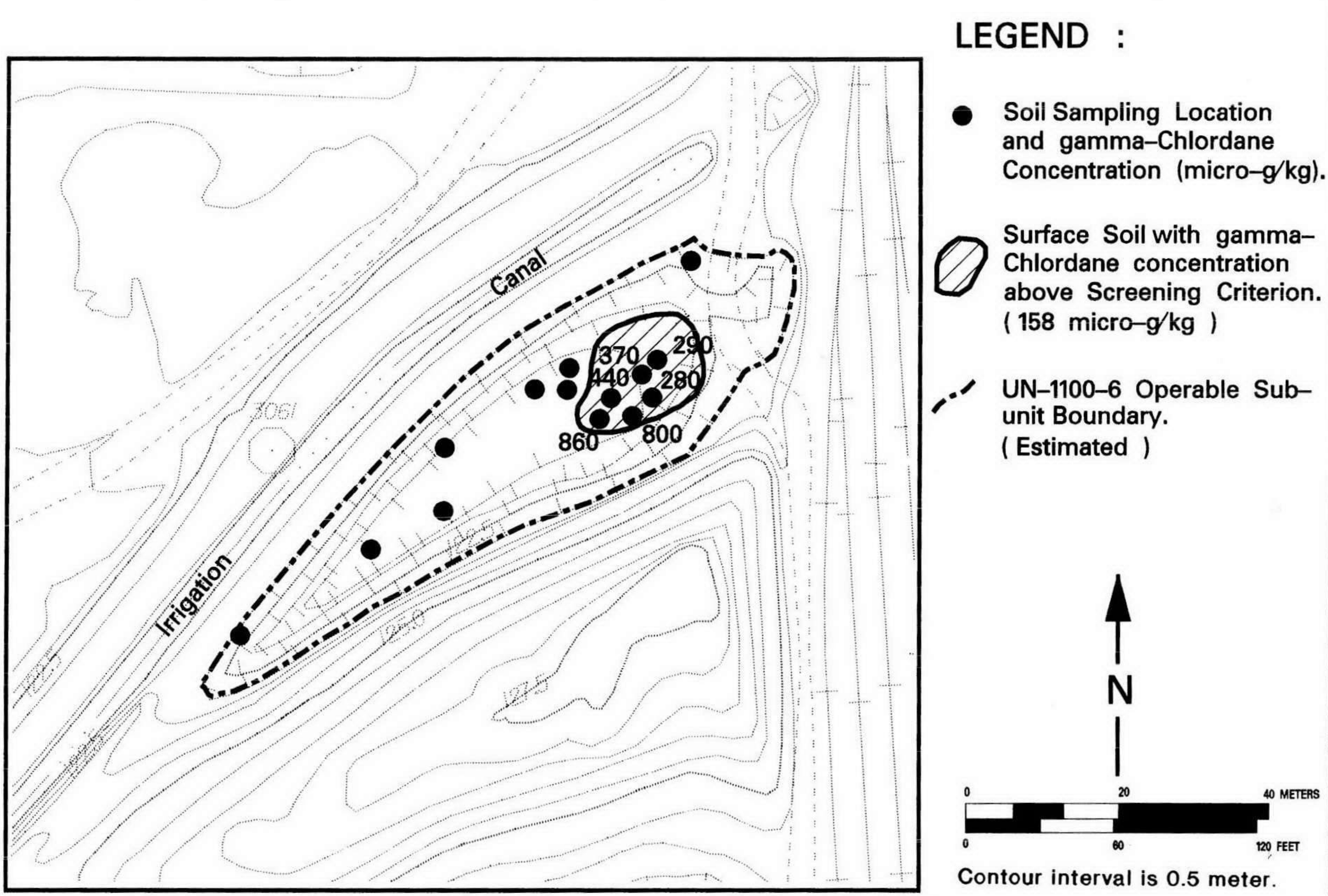
UN–1100–6, Discolored Soil Site – alpha–Chlordane Distribution in Surface Soils at Concentrations above a UTL 170 micro–g/kg.

Figure 4–4



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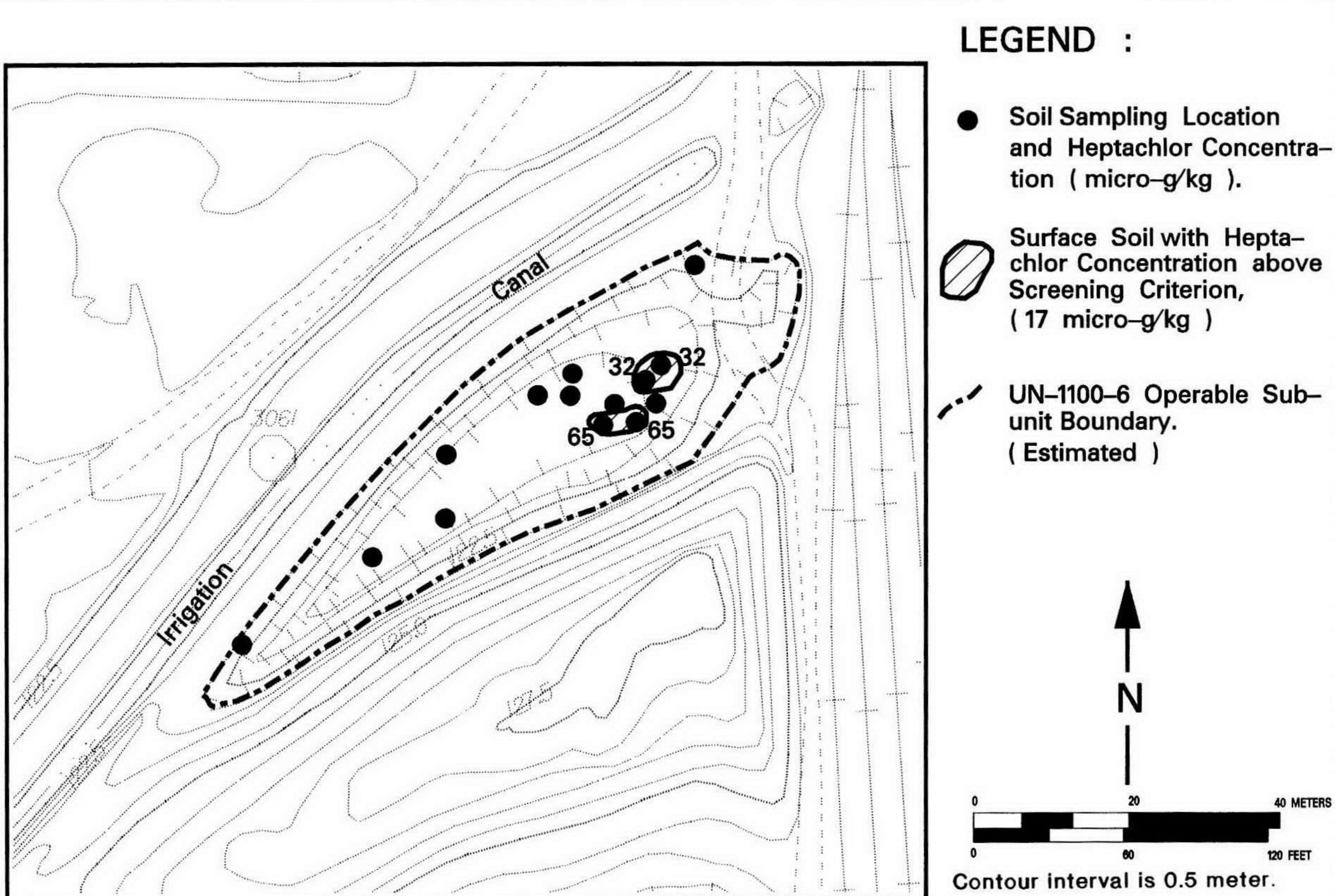
UN–1100–6, Discolored Soil Site – gamma–Chlordane Distribution in Surface Soils at Concentrations above a UTL of 158 micro–g/kg.

Figure 4–5



UN-1100-6, Discolored Soil Site - Heptachlor Distribution in Surface Soils at Concentrations above a UTL of 17 micro-g/kg.

Figure 4-6

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figure 7-1). Subsurface sampling was not performed at this subunit, but based on field observations, the soil staining appears to be limited to the top 20.3 to 25.4 cm (8 to 10 in) of soil.

Other contaminants (zinc; DDT; 2-hexanone; and 1,1,1-trichloroethane) occur at levels that pose no known substantive risks to public health or the environment. Lead is present at levels below regulatory cleanup criteria.

4.6 EPHEMERAL POOL

The contaminants detected at the Ephemeral Pool subunit are listed in paragraph 3.6.1. The preliminary risk-based screening for the identified contaminants is presented in table 4-6. Chlordane, heptachlor, and PCB's are the contaminants of potential concern at this subunit. Heptachlor was detected in one of two soil samples collected within the subunit during the Phase I investigation. The exact position of the sample site within the subunit is uncertain due to the lack of a sample location survey at the time the sample was collected. During Phase II soil sampling, heptachlor was not detected. Chlordane was identified at all sampling locations during the Phase II investigation with relatively high concentrations detected at either end of the Ephemeral Pool feature; sample sites E-1, E-5, and E-6. Elevated PCB concentrations were identified at sample locations E-2 and E-3 (figure 4-7). Sampling of subsurface soils was not performed during either the Phase I or Phase II investigations. It is assumed that both the PCB and chlordane contaminants are restricted to near-surface soils due to their relative immobility in soil/water systems. Because of their relative immobility, it was deemed to be an inefficient use of time given the project schedules, and not cost effective to perform sampling of the subsurface soils at the Ephemeral Pool. The vertical extent of contamination will be determined by soil sampling and analysis during site remediation (see sections 7 and 8).

Other contaminants (zinc, Endosulfan II, and Endrin) are measured at levels that pose no known substantive risk to the environment or public health. Lead is measured at levels below cleanup criteria.

4.7 HORN RAPIDS LANDFILL

As listed in paragraph 3.7.1, numerous inorganic contaminants were encountered in the surface and subsurface soils of HRL. The only subsurface organic contaminants detected were PCB's in borehole HRL-4 and in exploration trench test pit (TP)-1.

Table 4-6. Preliminary Risk-Based Screening for Soil Contaminants at the Ephemeral Pool.

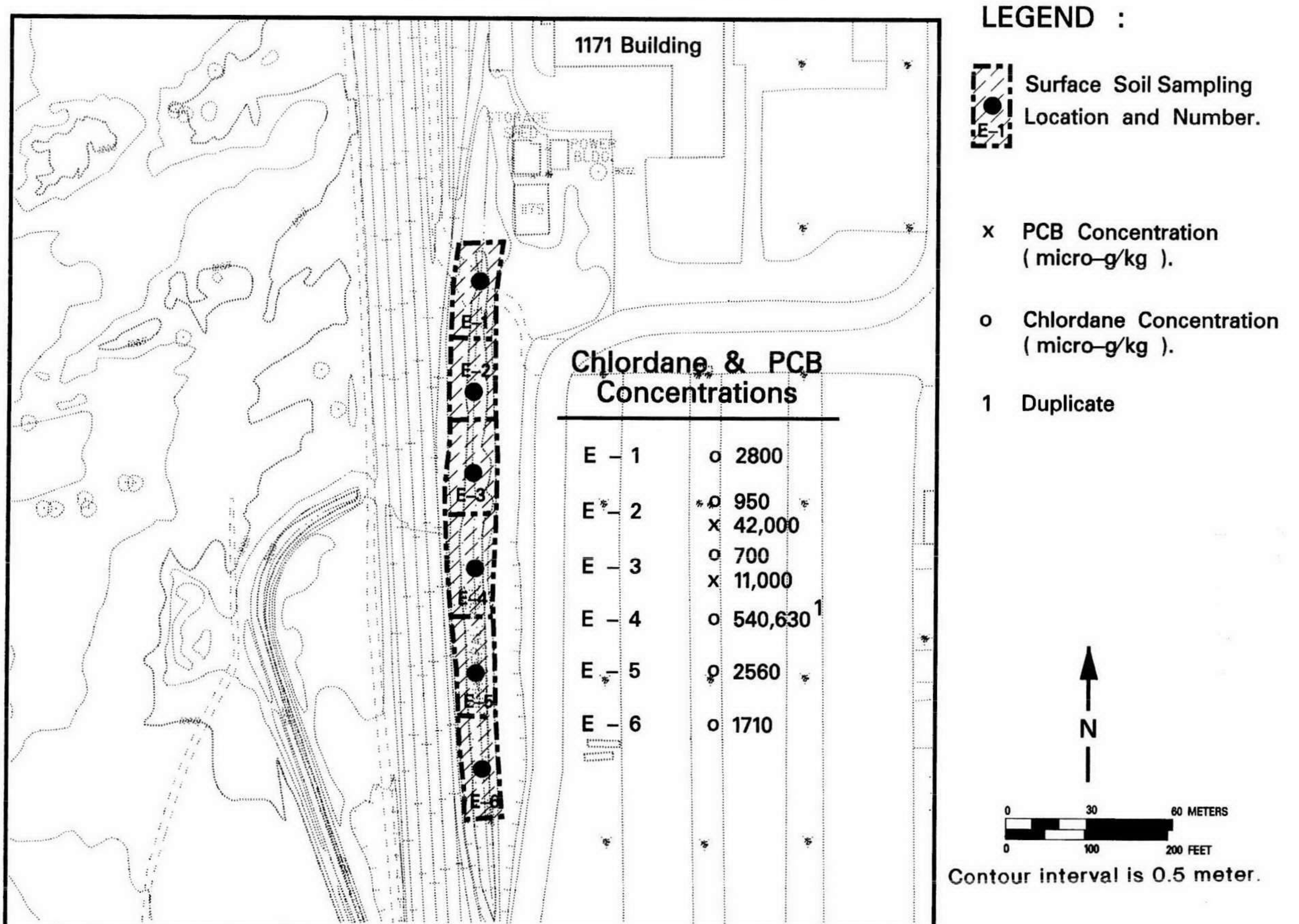
Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Lead	54.2	ND	--	ND	--	ND	--	ND	--	500-1,000[e]
Zinc	67.5	2.0E-01[b]	1,600	--	--	--	--	--	--	--
Chlordane	2.8	6.0E-05[a]	0.48	--	--	1.3E+00[a]	0.049	1.3E+00[a]	13	--
Endosulfan II	0.16	5E-05[a]	0.4	--	--	--	--	--	--	--
Endrin	0.039	3E-04[a]	2.4	--	--	--	--	--	--	--
Heptachlor	0.029	5.0E-04[a]	4.0	--	--	4.5E+00[a]	0.014	4.5E+00[a]	3.6	--
PCB's	42	--	--	--	--	7.7E+00[a]	0.008	7.7E+00[c]	2.1	1-25[d]

[a]Integrated Risk Information System (IRIS, EPA 1992a)
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1991)
[c]Surrogate inhalation SF assumed to be equal to PCB oral SF
[d]40 CFR 761
[e]EPA 1989b

-- Indicates not available

ND = Not determined

Note: Shaded areas indicate screening criterion exceeded



Ephemeral Pool – Chlordane and PCB Distribution in Surface Soils.

Figure 4–7

Table 4-7 summarizes the results of the preliminary risk-based screening for soil contaminants at HRL. The COPC for the HRL subunit are:

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Copper
- Cyanide
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Silver
- Thallium
- Vanadium
- Zinc
- Beta-HCH
- DDT
- Chlordane
- Endosulfan II
- Endrin
- Heptachlor
- Napthalene
- PCB's
- Tetrachloroethene

4.7.1 Horn Rapids Landfill Soil Contaminants

The distribution of each contaminant within the HRL subunit are discussed in the following paragraphs. UTL's for surface and subsurface soil contaminants were presented in tables 3-1 and 3-2, respectively. Maps providing the locations and designations of all surface sampling and borehole locations within the HRL subunit were included in figures 3-6 and 3-9.

4.7.1.1 Antimony. Antimony was detected in surface soil samples at concentrations above the UTL levels at three locations in the east-central portion of the landfill. Figure 4-8 shows the distribution of this analyte in the surface soils. Antimony was detected in only a single subsurface sampling location; borehole HRL-2 within the depth interval of 1.6 to 2.2 m (5.1 to 7.1 ft).

4.7.1.2 Arsenic. Arsenic was not detected in surface soils at concentrations above the UTL for this substance. Subsurface distribution was sporadic. It was detected in exploration trenches 7, 8, and 11 at depths between 1.2 and 1.5 m (4 and 5 ft), in borehole HRL-3 at a depth of 7.3 m (24 ft), and in borehole HRL-7 at an approximate depth of 3.0 m (10 ft).

4.7.1.3 Barium. The distribution of barium in the surface soils at HRL in concentrations above a UTL of 120.1 mg/kg is presented in figure 4-9. Only one subsurface sample yielded an elevated barium concentration; B00Z59, obtained from a depth of 1.2 m (4.0 ft) in exploration trench TP-11 (see figures 3-6 and 3-9).

4.7.1.4 Beryllium. Figure 4-10 presents the beryllium distribution at concentrations above UTL levels in surface soils at the HRL subunit. Beryllium was widespread in subsurface samples obtained from borings HRL-2 through -10. Concentrations above the subsurface UTL were detected throughout the length of the soil column penetrated [*i.e.*, depths of 4.6 to 8.5 m (15 to 28 ft)]. As discussed in section 2.0, these boreholes were sited to intentionally avoid penetrating assumed locations where waste had been buried during landfill operation. These boreholes, therefore, are assumed to penetrate undisturbed soil deposits for much of their depth. Only a single soil sample collected from a known disturbed area contained an

Table 4-7. Preliminary Risk-Based Screening for Soil Contaminants at the Horn Rapids Landfill. (sheet 1 of 2)

Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Antimony	15.6	4.0E-04[a]	3.2	--	--	--	--	--	--	--
Arsenic	6.6	3.0E-04[a]	2.4	--	--	1.7E+00[+]	0.038	5.0E+01[a]	1.1[a]	--
Barium	1320	7.0E-02[a]	560	1.0E-04[b]	320	--	--	--	--	--
Beryllium	1.3	5.0E-03	41	--	--	4.3E+00[a]	0.015	8.4E+00[a]	1.9	--
Cadmium	2.4	1.0E-03[a]	8.0	--	--	--	--	6.1E+00[a]	2.7	--
Chromium	1250	5.0E-03[a]	40	--	--	--	--	4.1E+01[a]	0.4	--
Cobalt	42.5	6.0E-02[f]	480	--	--	--	--	--	--	--
Copper	1280	4.0E-02[f]	320	--	--	--	--	--	--	--
Cyanide	0.56	2.0E-02[a]	160	--	--	--	--	--	--	--
Lead	854	ND	--	ND	--	ND	--	ND	--	500-1,000[d]
Manganese	501	1.0E-01[a]	800	1.1E-04[a]	350	--	--	--	--	--
Mercury	1.3	3.0E-04[b]	2.4	8.6E-05[b]	280	--	--	--	--	--
Nickel	557	2.0E-02[a]	160	--	--	--	--	8.4E-01[b]	19	--
Selenium	0.97	5.0E-03[b]	44	--	--	--	--	--	--	--
Silver	7.7	5.0E-03[a]	40	--	--	--	--	--	--	--
Thallium	3.1	7.0E-05[a]	0.56	--	--	--	--	--	--	--
Vanadium	101	7.0E-03[b]	56	--	--	--	--	--	--	--
Zinc	3160	2.0E-01[b]	1,600	--	--	--	--	--	--	--
Beta-HCH	0.094	--	--	--	--	1.8E+00[a]	0.036	1.8E+00[a]	9.1	--
DDT	1.98	5.0E-04[a]	4.0	--	--	3.4E-01[a]	0.19	3.4E-01[a]	48	--
Endosulfan II	0.11	5.0E-05[a]	0.4	--	--	--	--	--	--	--

Table 4-7. Preliminary Risk-Based Screening for Soil Contaminants at the Horn Rapids Landfill. (sheet 2 of 2)

Parameter	Maximum Detected Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at HQ=0.1 (mg/kg)	Oral SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF $(mg/kg\text{-}d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Endrin	0.42	3.0E-04[a]	2.4	--	--	--	--	--	--	--
Heptachlor	0.02	5.0E-04[a]	4.0	--	--	4.5E+00[a]	0.014	4.5E+00[a]	3.6	--
Naphthalene	8.2	4.0E-02[b]	320	--	--	--	--	--	--	--
PCBs	102	--	--	--	--	7.7E+00[a]	0.008	7.7E+00[h]	2.1	1-25[i]
Tetrachloroethane	0.006	1.0E-02[a]	80	--	--	5.2E-02[f]	1.2	2.0E-03[f]	8,200	--

[a]Integrated Risk Information System (IRIS, EPA 1992a)
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1991 or EPA 1992b)
[c]Based on 30% absorption of inhaled arsenic (EPA 1992b)
[d]EPA 1989b
[e]Surrogate inhalation SF assumed to equal BEHP oral SF
[f]EPA-Region 10 (see Appendix A)
[g]Surrogate oral and inhalation RfDs based on 2-butanone (HEAST, EPA 1992b)
[h]Surrogate inhalation SF assumed to be equal to PCB oral SF
[i]40 CFR 761
[+]Surrogate based on proposed arsenic unit risk of 5E-05 $\mu g/L$ (EPA 1991)
-- Indicates not available
ND = Not Determined
Note: Shaded areas indicate screening criterion exceeded

elevated concentration of beryllium. Sample B00ZV3, gathered from a depth of 1.5 m (5 ft) in exploration trench TP-8, contained beryllium at a level exceeding the UTL.

4.7.1.5 Chromium. Chromium distribution in surface soils is illustrated in figure 4-11. It appears to be generally isolated to the eastern edge of the landfill, appearing in samples obtained from shallow depressions in the ground surface. Subsurface chromium contamination is scattered throughout the subunit. Boreholes HRL-4, -5, -6, and -8 show concentrations above UTL values at depths of approximately 4.6 m (15 ft). One soil sample from HRL-6 at a depth of 7.6 m (25 ft) also showed elevated chromium. Samples obtained during Phase II characterization of the landfill's waste disposal trenches contained elevated concentrations of chromium in exploration trenches TP-3A, -4, -5, and -11 at depths of 5.8, 3.7, and 1.2 m (19, 12, and 4 ft), respectively.

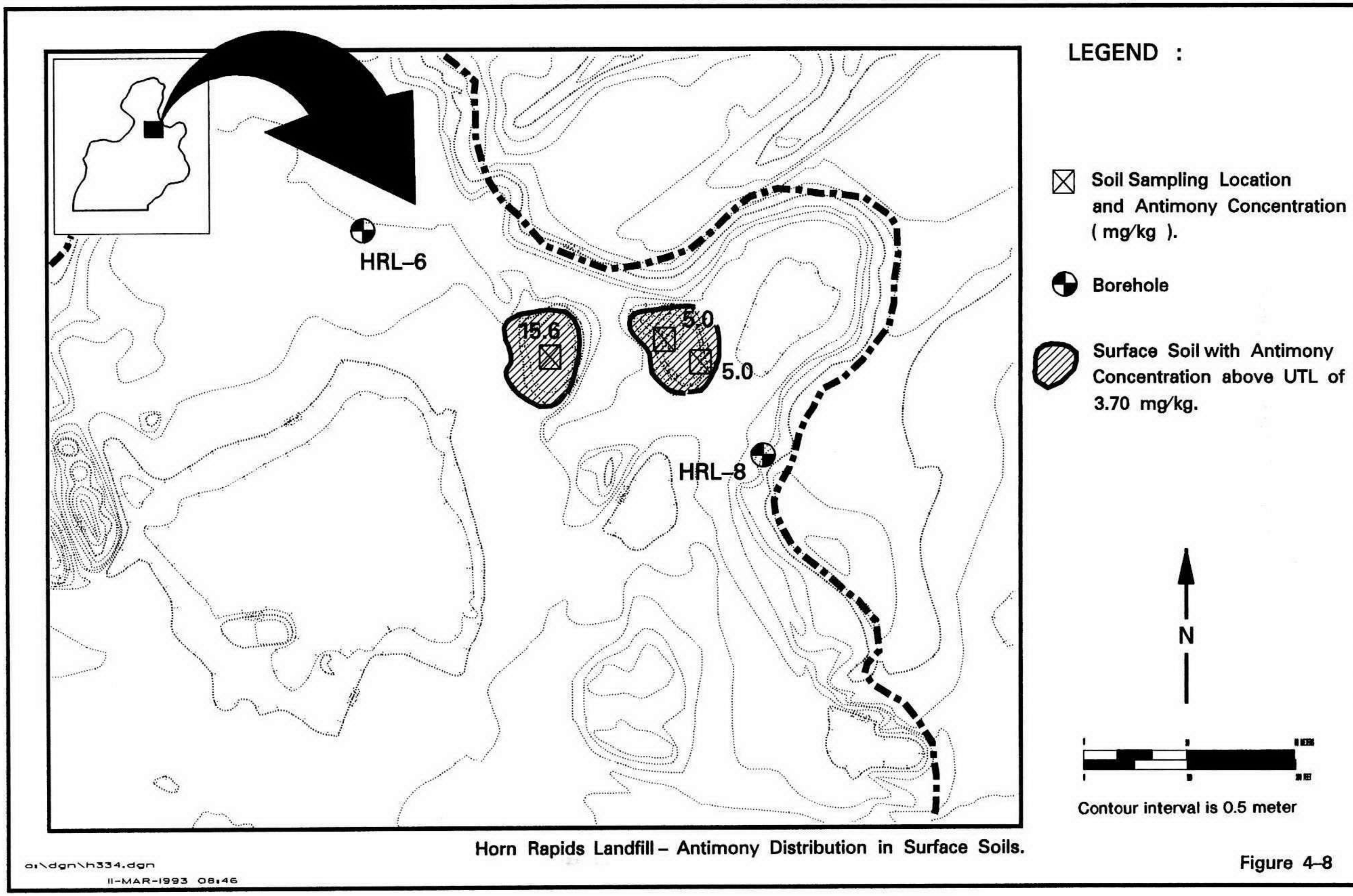
4.7.1.6 Copper. The distribution of copper in the surface soils of HRL at concentrations above the UTL value is depicted in figure 4-12. Areas of high copper concentrations are generally restricted to depressions in the ground surface or to the base of relatively steep soil slopes. Copper was also a common contaminant detected above UTL values in soil samples obtained from the subsurface. Elevated levels of copper were detected in boreholes HRL-4, -5, -6, -8, -9, and -10 and appeared to be randomly distributed throughout the depth of natural soil deposits sampled. Elevated levels of copper were also detected in soil samples obtained from exploration trenches TP-3A, -4, -5, -8, and -11.

4.7.1.7 Lead. Figure 4-13 illustrates the distribution of lead present at concentrations above UTL levels in the surface soil of HRL. With few exceptions, the locations of elevated lead levels are within surface depressions of the subunit. Elevated levels of lead in the subsurface were detected in soil samples obtained from boreholes HRL-6 and HRL-10. Both boreholes showed elevated lead concentrations at a depth of approximately 6.1 to 7.6 m (20 to 25 ft). In addition, HRL-10 had elevated values at a depth of approximately 1.2 m (4.0 ft). Exploration trenches TP-3A, -4, -5, -7, -8, and -11 encountered elevated lead concentrations at depths ranging from 1.2 to 5.8 m (4 to 19 ft). There was no pattern to the lead distribution in the subsurface at these locations.

4.7.1.8 Manganese. Manganese was not detected at elevated concentrations in surface soils at HRL. Elevated levels of manganese were detected in subsurface soils in one sample from borehole HRL-2 [depth internal 3.0 to 4.1 m (9.8 to 13.3 ft)], one sample from borehole HRL-4 [4.5 to 5.2 m (14.6 to 16.9 ft)], three samples from borehole HRL-5 [2.9 to 5.4 m (9.4 to 17.6 ft)], three samples from HRL-8 [1.8 to 5.3 m (5.9 to 17.3 ft)], and a single sample from HRL-10 [0.7 to 1.22 m (2.3 to 4.0 ft)]. Soil samples collected from trenches TP-1, TP-3B, TP-8, and TP-11 had elevated concentrations of manganese at depths of 2.7, 2.1 to 2.3, 1.5, and 1.2 m (9.0, 7.0 to 7.5, 5.0, and 4.0 ft), respectively.

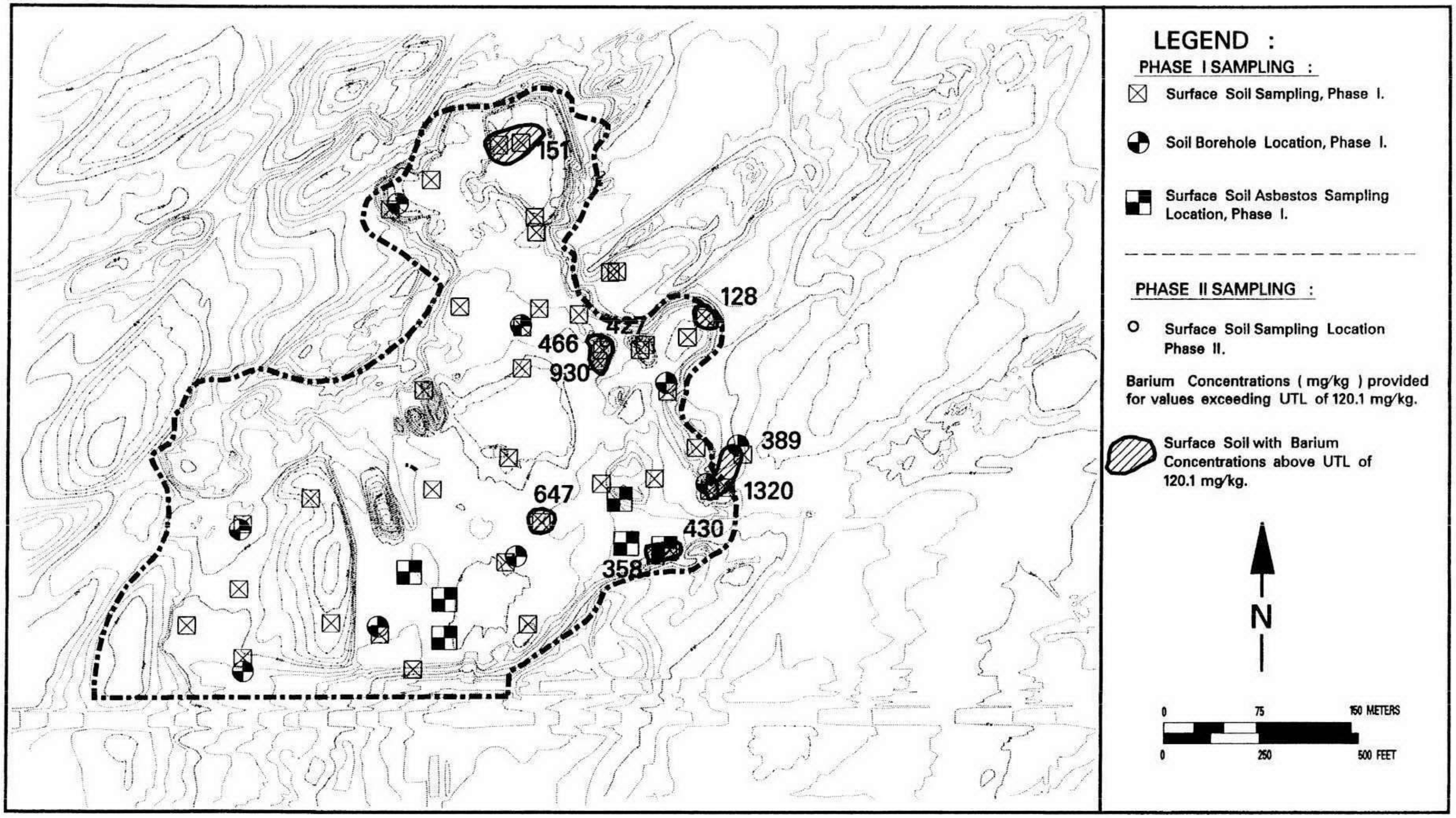
4.7.1.9 Nickel. Nickel was detected at the HRL subunit at concentrations above UTL values in a single surface sample located in the extreme northern portion of the facility. Figure 4-14 presents the location of elevated nickel concentrations in the HRL surface soils. The distribution of nickel in the subsurface is scattered, as there appeared to be no consistency in the depths of elevated nickel concentrations from borehole-to-borehole. Boreholes HRL-4, -5, -6, -8, and -10 showed elevated nickel in soil samples collected from

9 3 1 2 9 3 3 0 2 4 9



Horn Rapids Landfill – Antimony Distribution in Surface Soils.

Figure 4-8



Contour interval is 0.5 meter.

Horn Rapids Landfill – Barium Distribution in Surface Soils.

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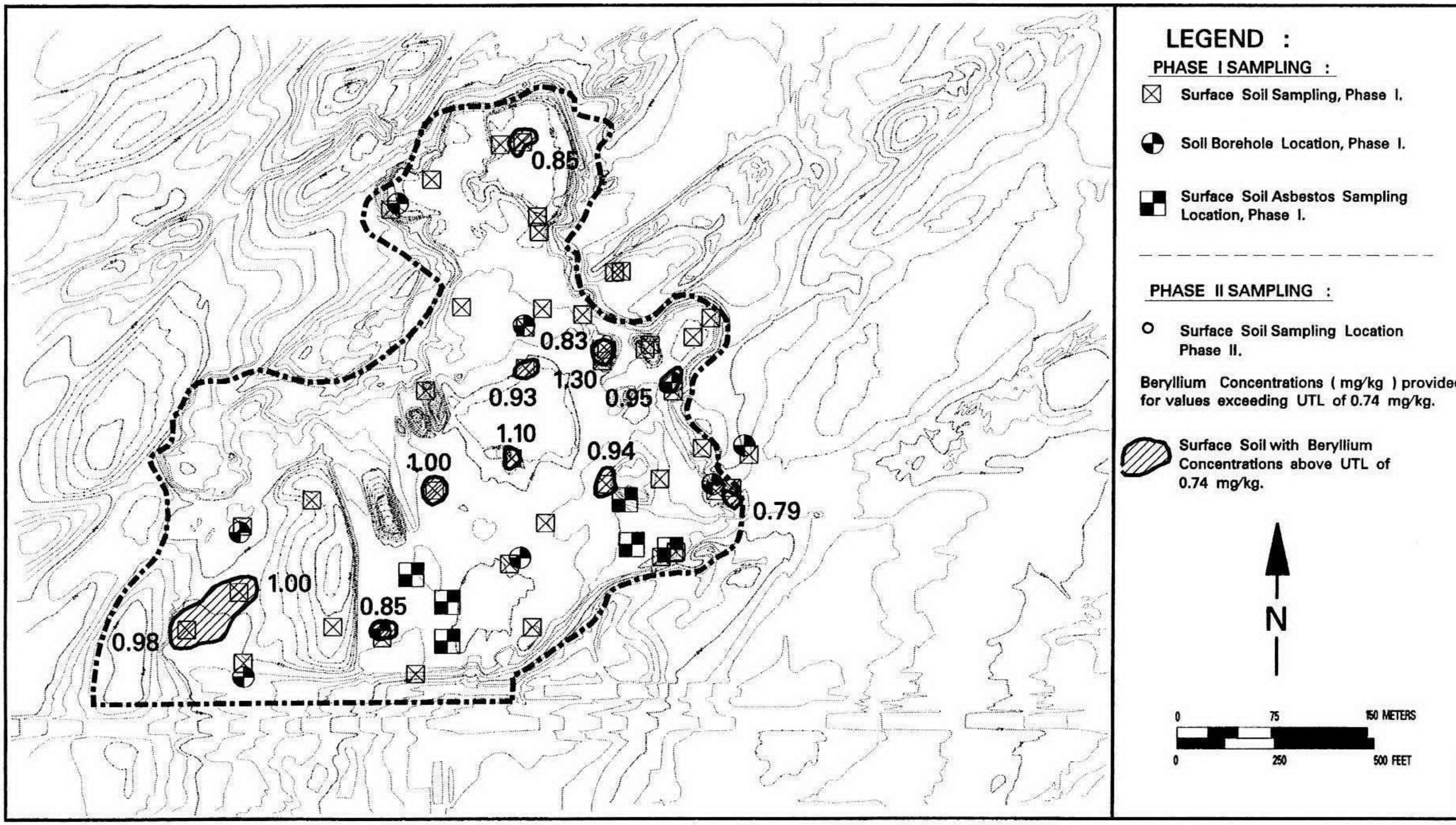
Figure 4-9



Contour interval is 0.5 meter.

Horn Rapids Landfill – Beryllium Distribution in Surface Soils.

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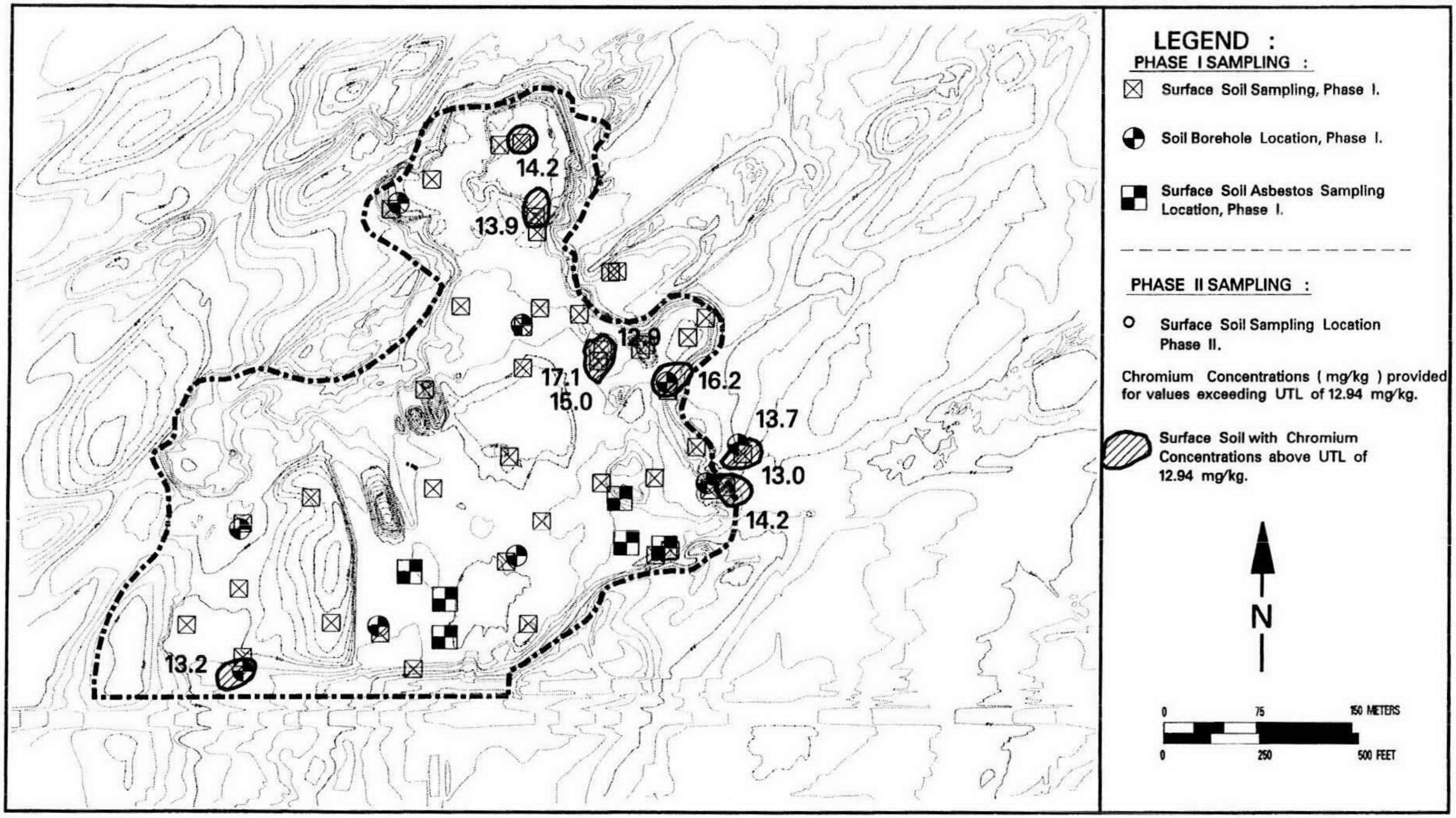
Figure 4-10



Contour interval is 0.5 meter.

Horn Rapids Landfill – Chromium Distribution in Surface Soils.

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Figure 4–11

varying depths. As with the boring samples, nickel was found randomly distributed in exploration trenches at levels above UTL levels. Soil samples collected from trenches TP-3A, -4, -5, -7, and -11 had elevated nickel at depths of 5.8, 3.7, 1.5, and 1.2 m (19, 12, 5, and 4 ft), respectively.

4.7.1.10 Thallium. A single surface soil sample in the extreme southeast corner of the subunit yielded thallium concentrations above UTL levels. Figure 4-15 shows the location of the elevated thallium within HRL. Borehole HRL-7 was the only location having elevated thallium in the subsurface. Soil samples obtained at the depth intervals of 3.9 to 4.6 m and 6.9 to 7.6 m (12.7 to 15.1 ft and 22.7 to 25.0 ft) during drilling of the borehole tested positive for thallium at concentrations exceeding UTL levels.

4.7.1.11 Vanadium. Vanadium was detected in two surface samples at concentrations exceeding UTL values; AH188 in the northern portion of the landfill, and AH203 in the southern portion. These sampling locations are presented in figure 4-16. Elevated concentrations of vanadium were not detected in subsurface soil samples collected from HRL.

4.7.1.12 Zinc. Concentrations of zinc in the surface soil at HRL exceeding UTL values were limited to samples collected from the bottoms of depressions located adjacent to the landfill's eastern and northern boundary slopes. These areas are shown on figure 4-17. Elevated concentrations of zinc were detected in subsurface soils sampled during the drilling of boreholes HRL-5, -6, and -10 at depths of approximately 3.0, 3.7, and 5.8 m (10, 12, and 19 ft), respectively. Zinc was also detected in soils excavated from exploration trenches TP-3A, -4, -5, -8, and -11 at depths varying from 1.2 to 5.8 m (4 to 19 ft).

4.7.1.13 beta-HCH (beta-hexachlorocyclohexane). Concentrations of beta-HCH above UTL values were only detected in surface samples collected during the Phase II investigation. Three sample locations adjacent to borehole HRL-4 contained elevated beta-HCH; HRL-1A, -2A, and -4A. Sampling locations are presented in figure 4-18.

4.7.1.14 DDT. The insecticides 4,4'DDD, 4,4'DDE, and 4,4'DDT were found in surface soils at concentrations above UTL values in isolated locations within HRL (see figures 4-19, 4-20, and 4-21 and 4-22, respectively). No subsurface concentrations of insecticides or pesticides were detected within the HRL subunit.

4.7.1.15 Heptachlor. A single heptachlor analysis obtained from surface soil samples exceeded UTL values for the HRL subunit. The heptachlor in sample AH203, located along the south central boundary of the landfill (figure 4-23), only slightly exceeded the UTL. No elevated concentrations of heptachlor were detected in soil samples collected from subsurface strata.

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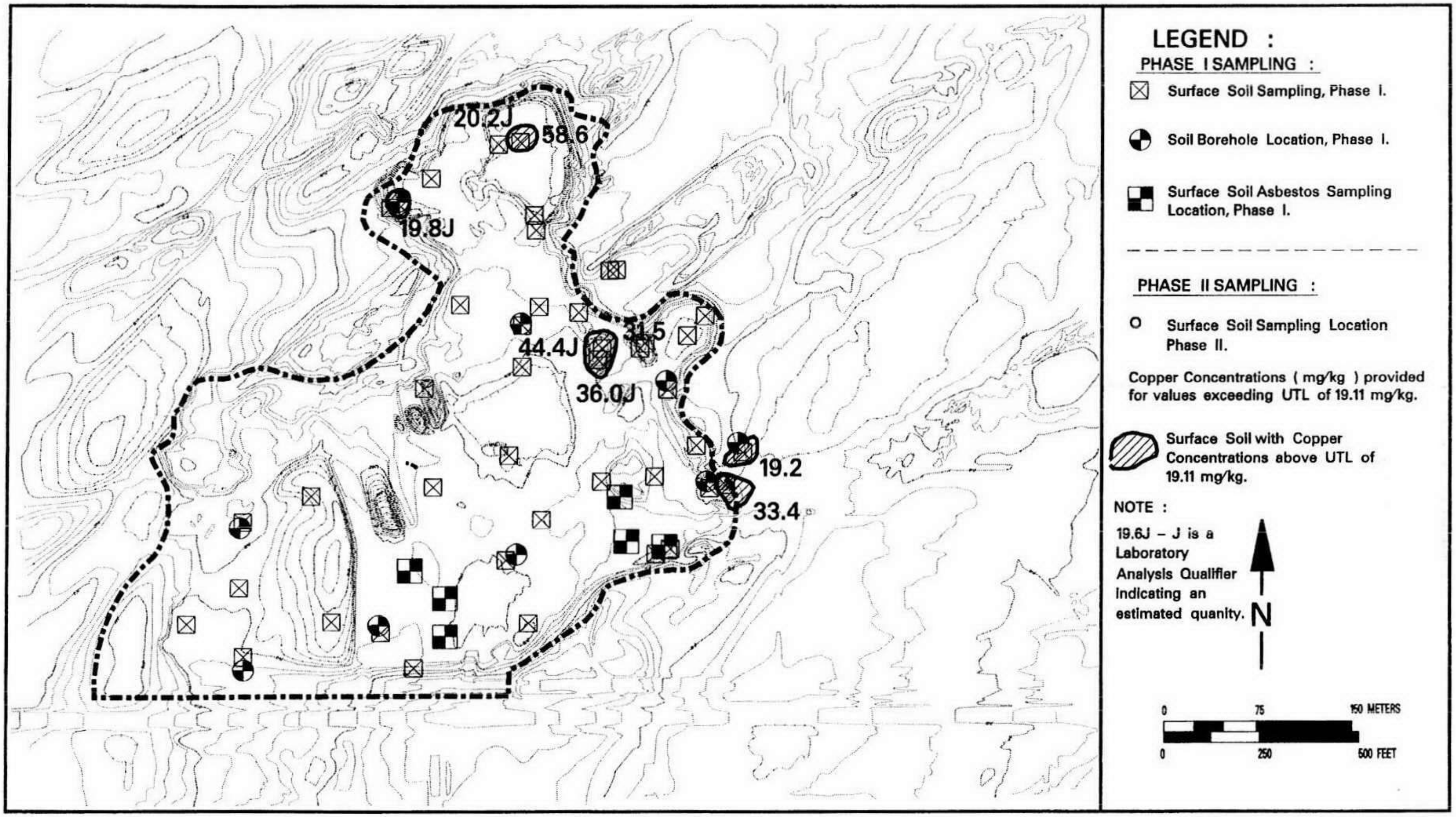

Contour interval is 0.5 meter.

Horn Rapids Landfill – Copper Distribution in Surface Soils.

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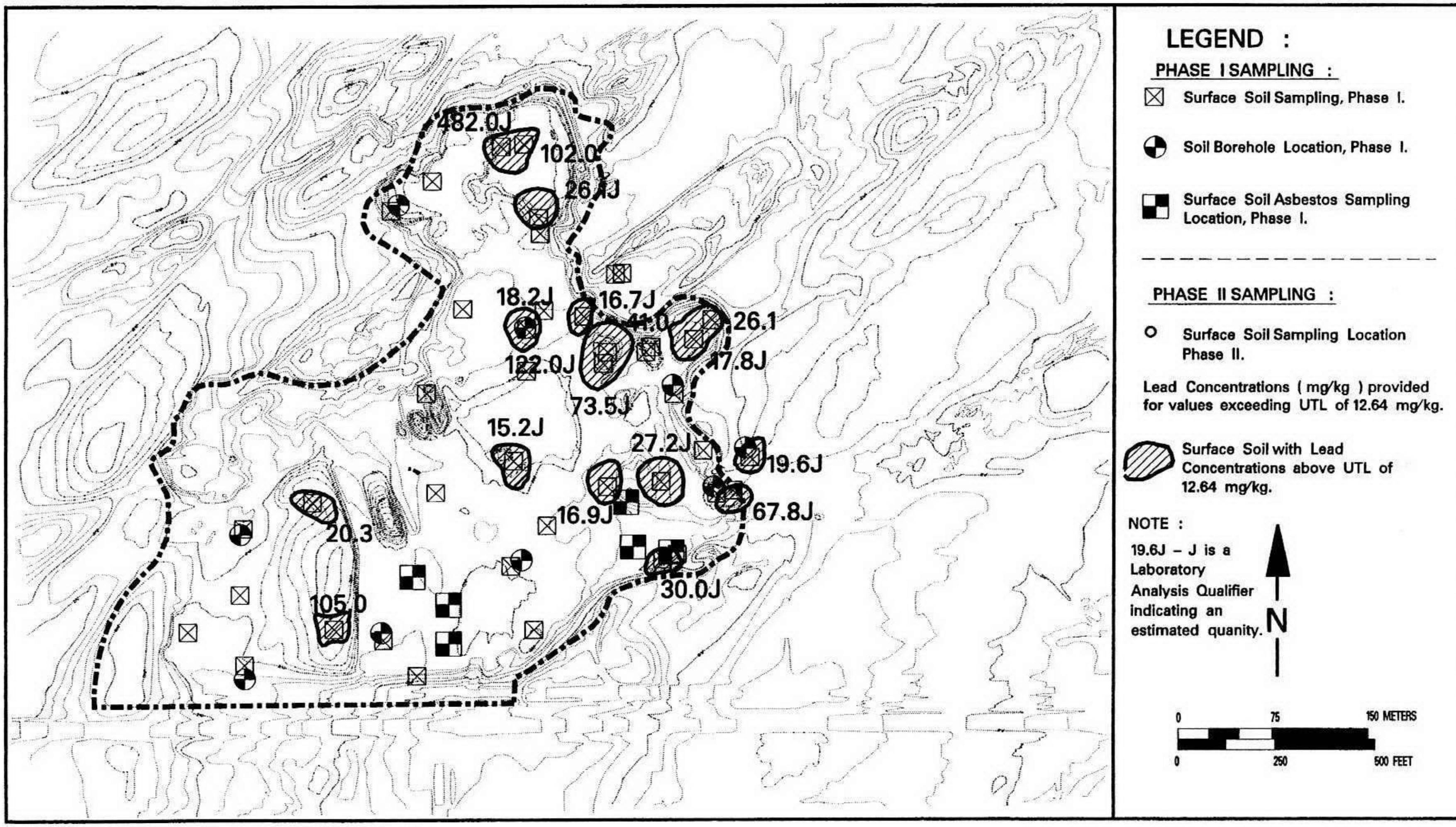
Figure 4-12



Contour interval is 0.5 meter.

Horn Rapids Landfill – Lead Distribution in Surface Soil.

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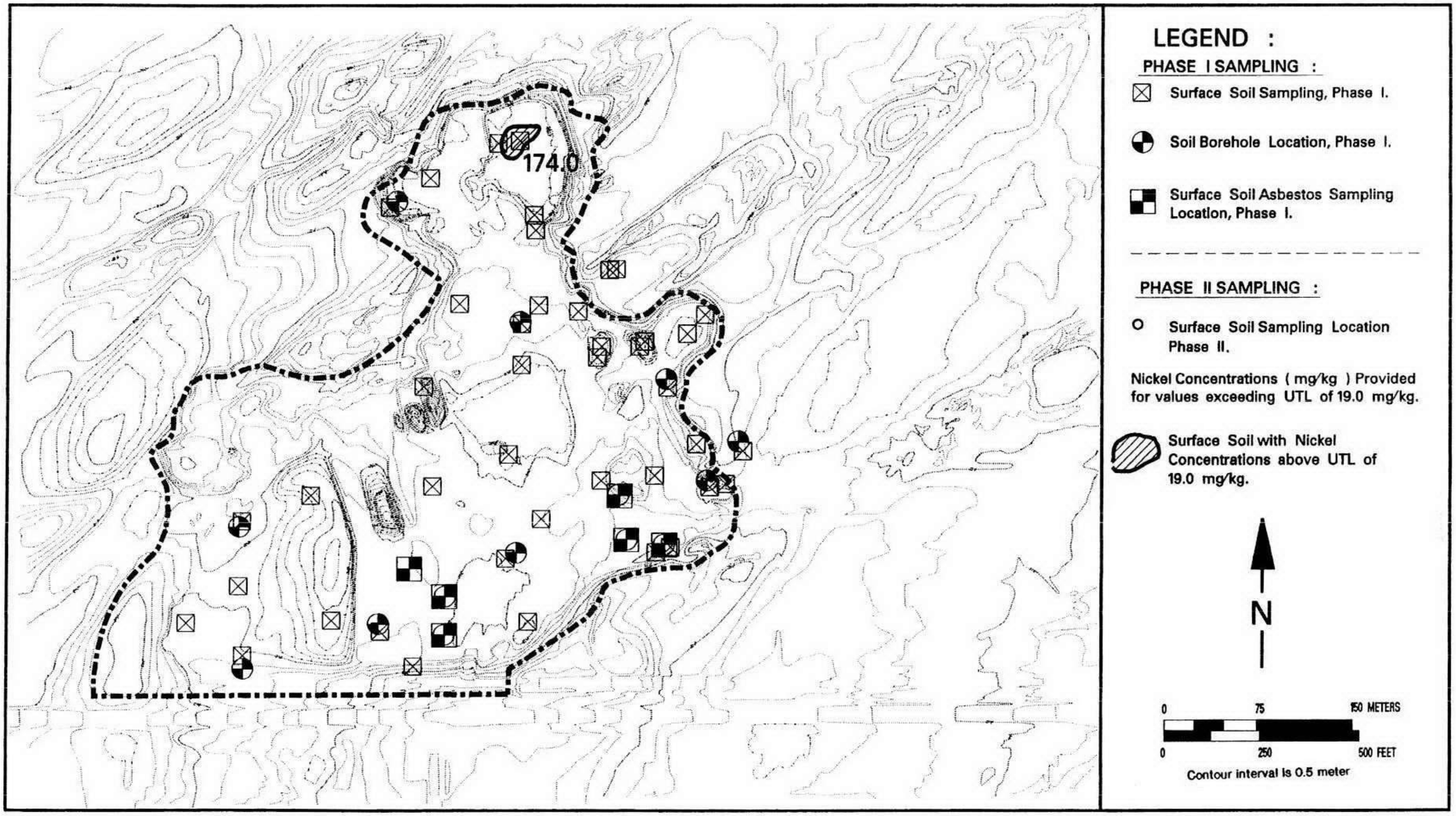
Figure 4–13



Horn Rapids Landfill – Nickel Distributionin Surface Soils.

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Figure 4-14

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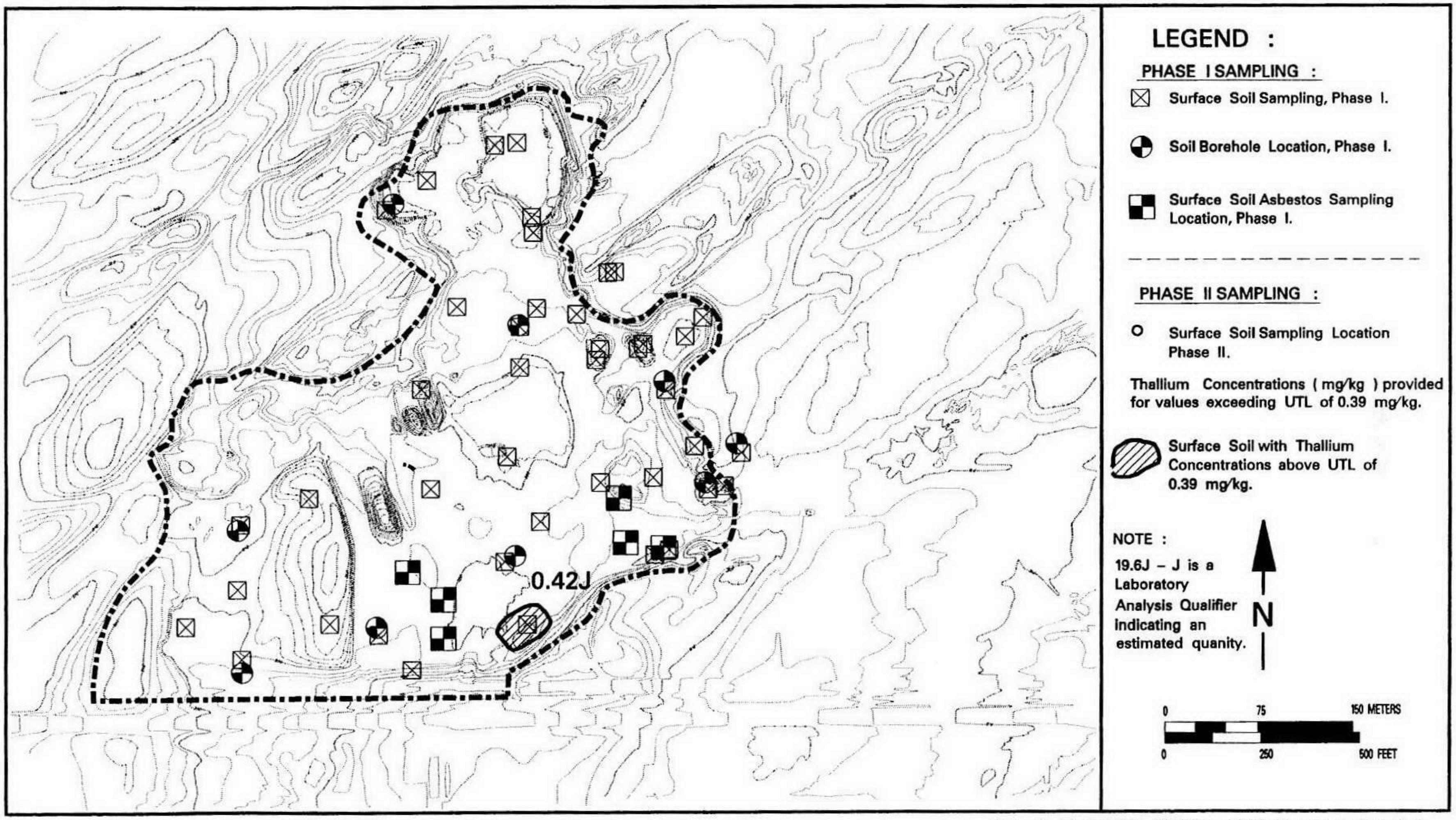

Contour interval is 0.5 meter.

Horn Rapids Landfill – Thallium Distribution in Surface Soils.

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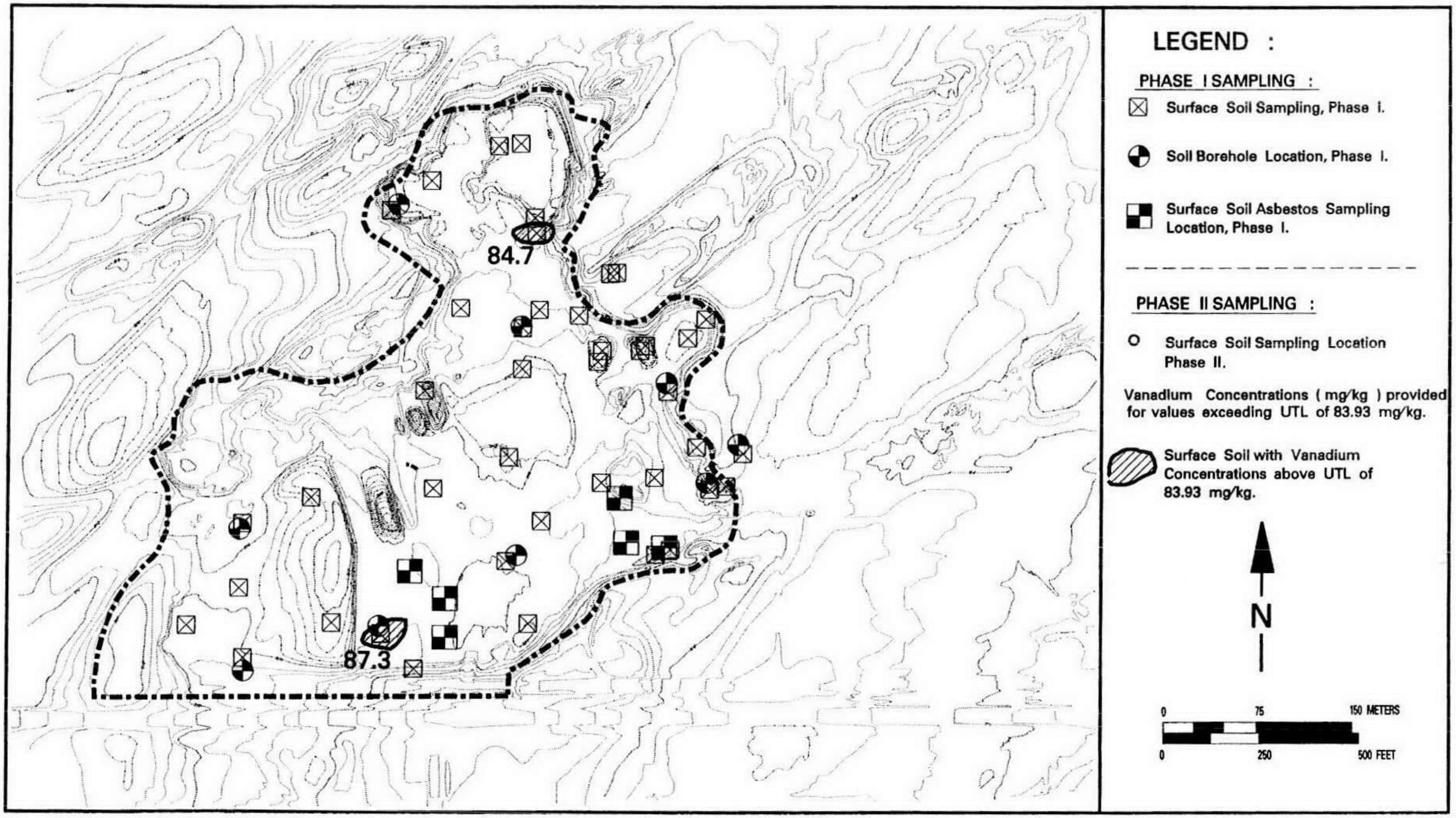
Figure 4–15



Contour interval is 0.5 meter.

Horn Rapids Landfill – Vanadium Distribution in Surface Soils.

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Figure 4-16

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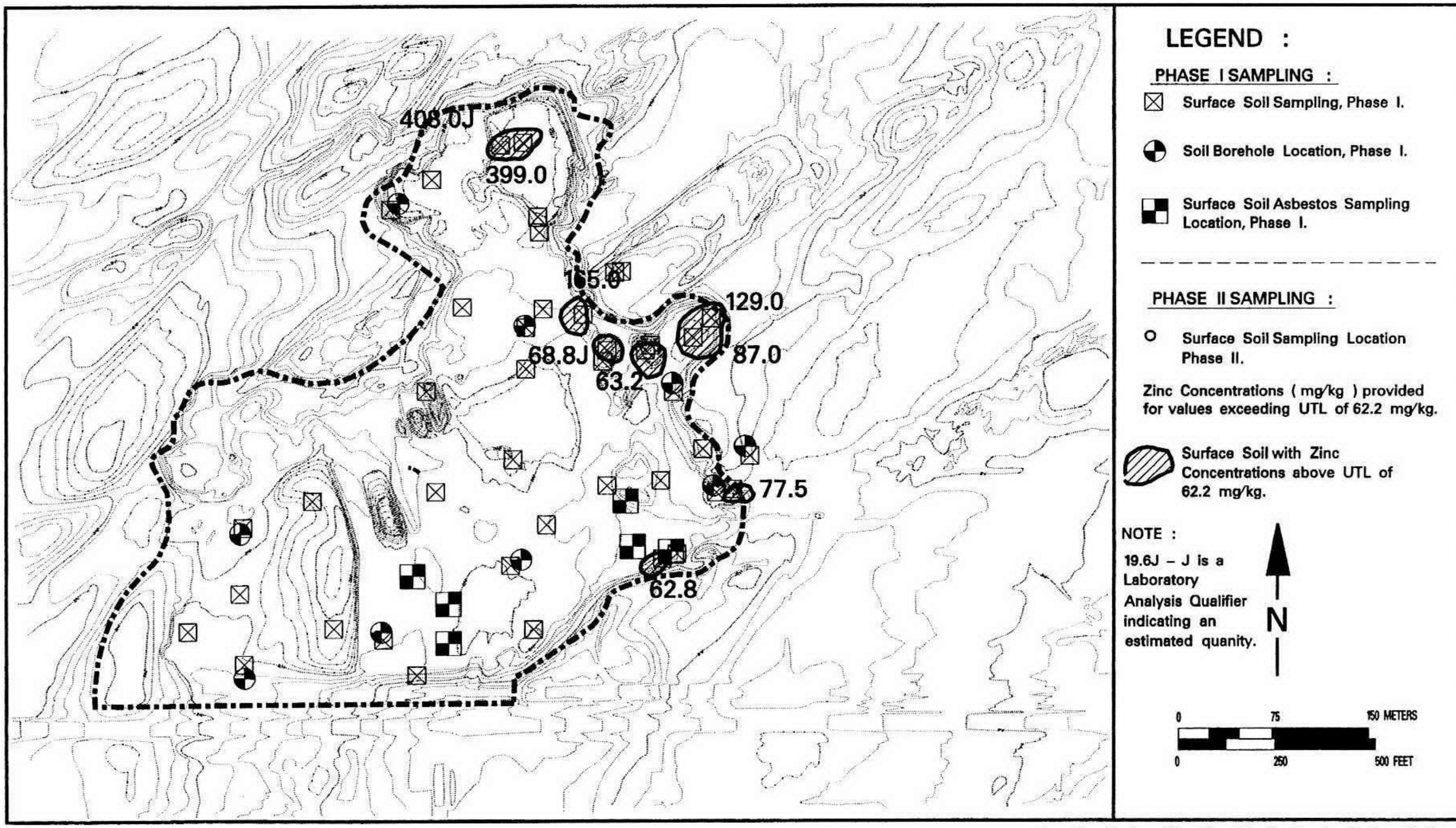

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Horn Rapids Landfill – Zinc Distribution in Surface Soils.

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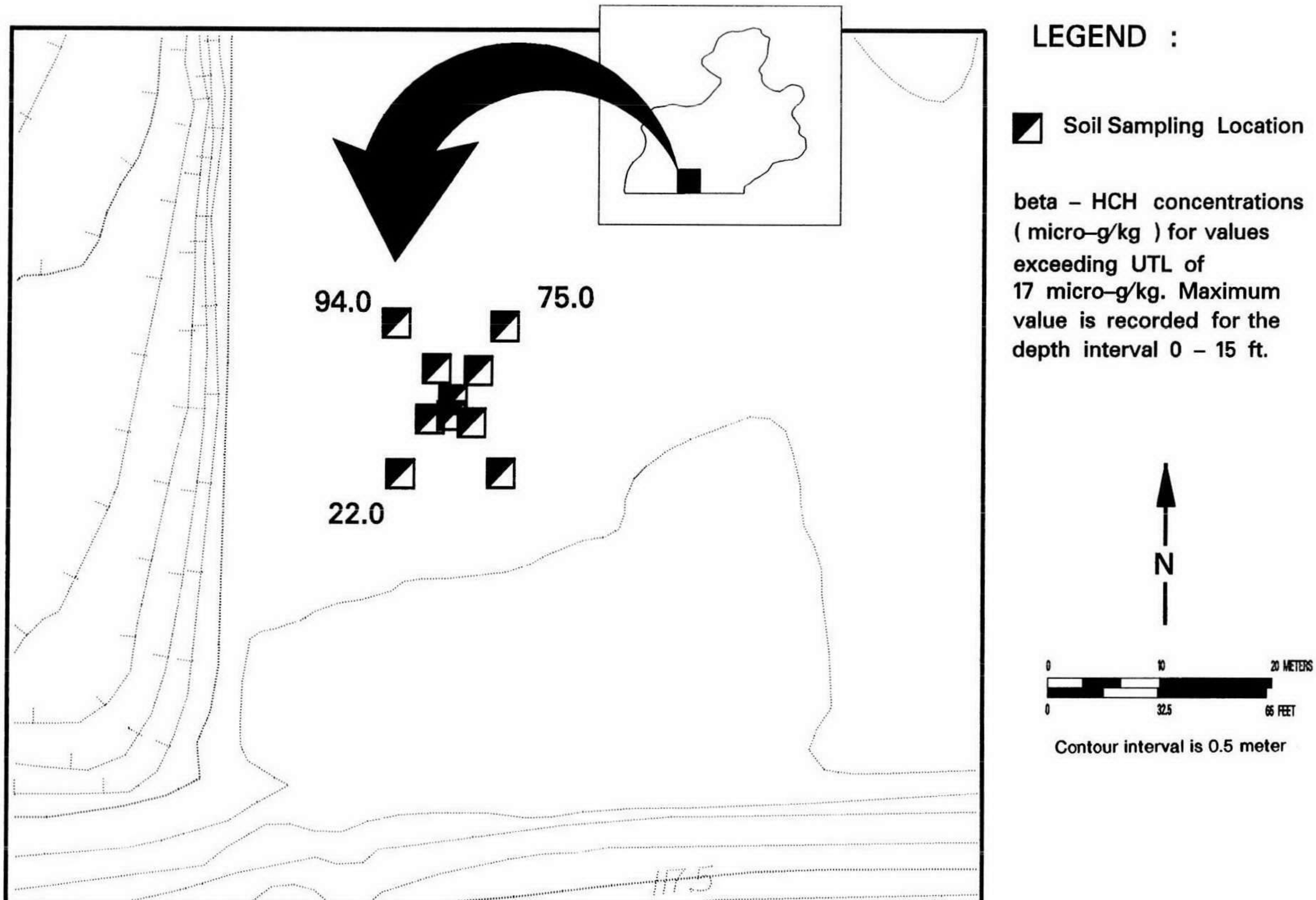
Figure 4-17



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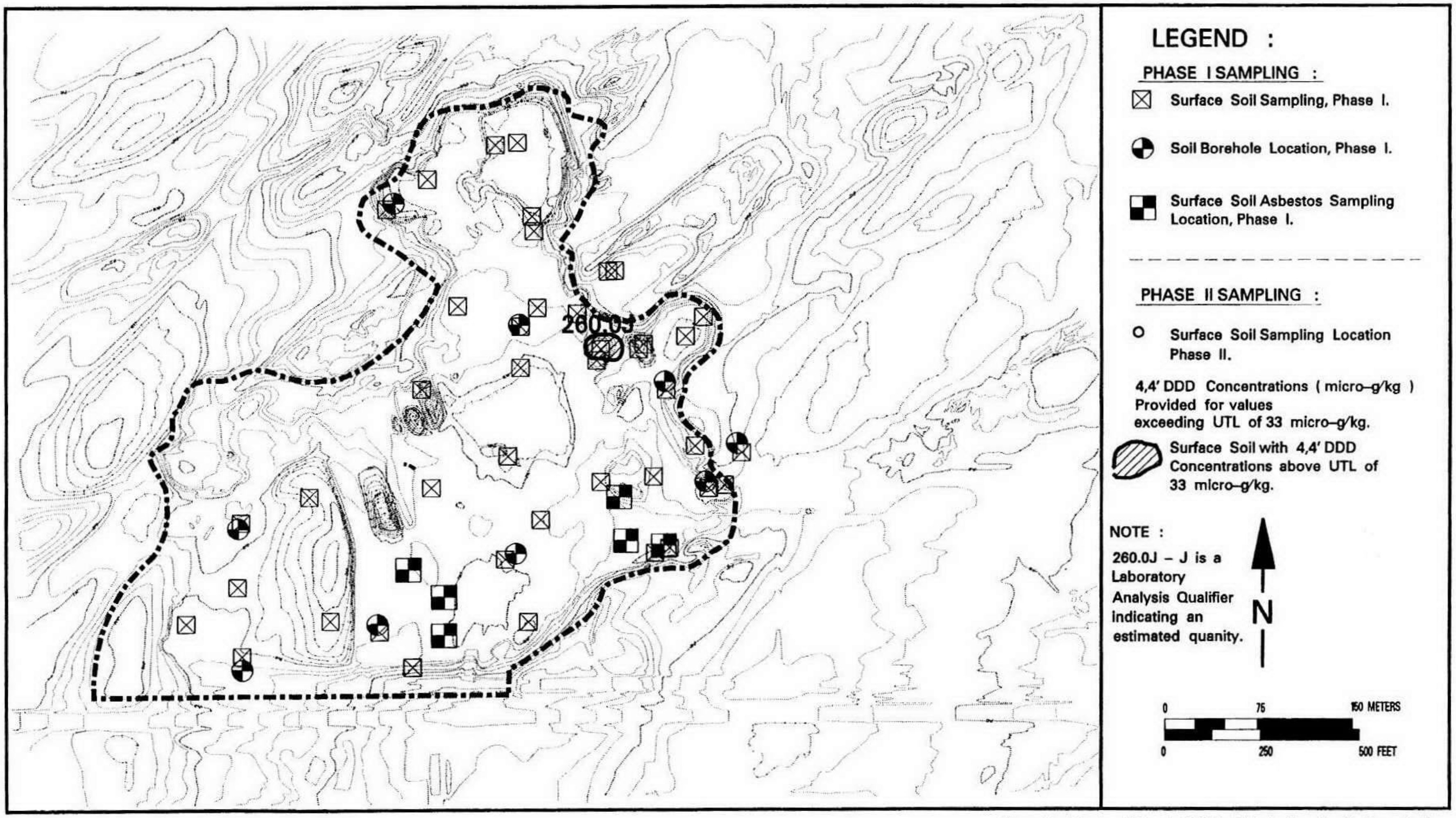
Horn Rapids Landfill – beta–HCH Distribution in Surface Soils.

Figure 4–18



Contour interval is 0.5 meter.

Horn Rapids Landfill – 4,4' DDD Distribution in Surface Soils.

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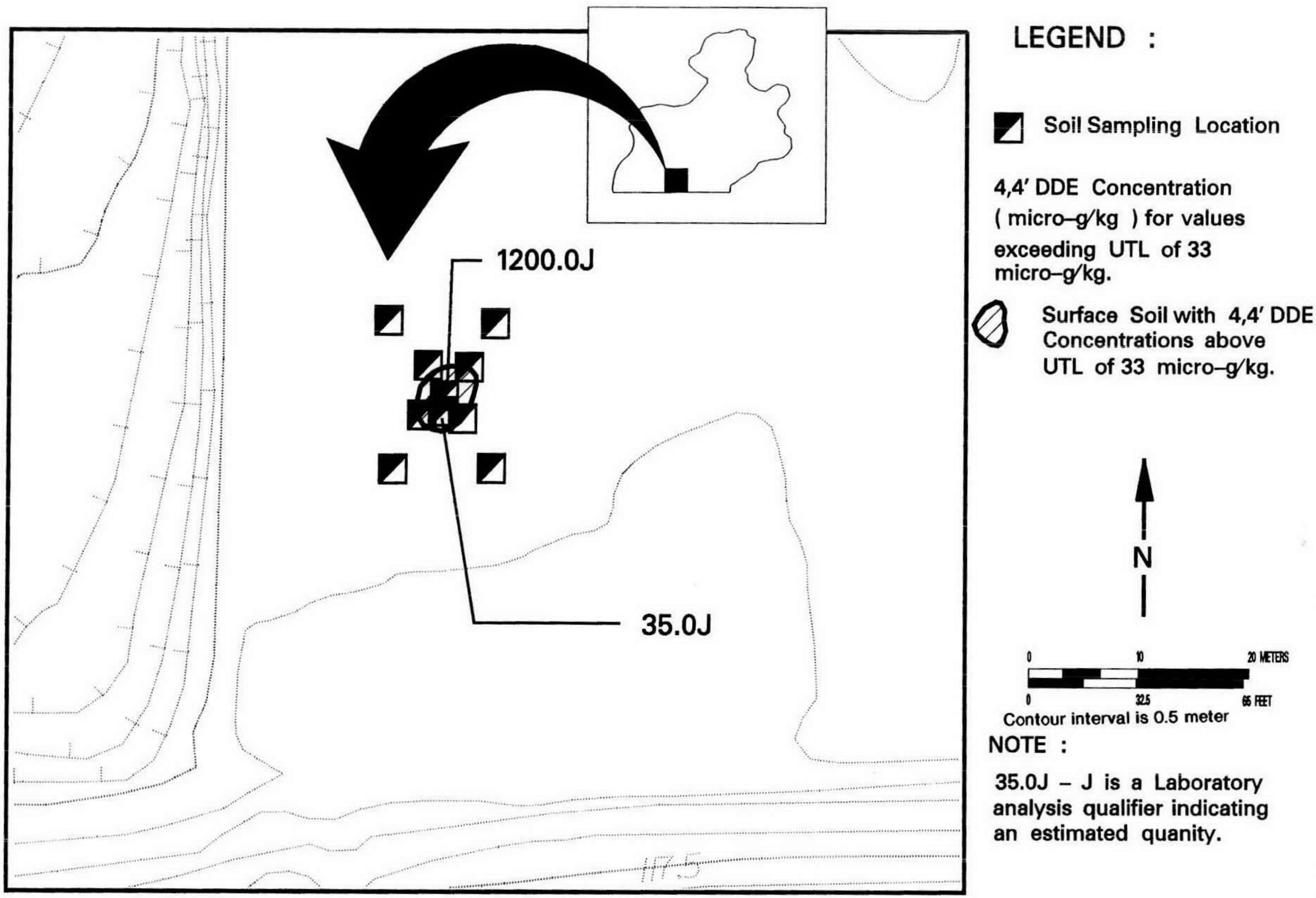
Figure 4-19



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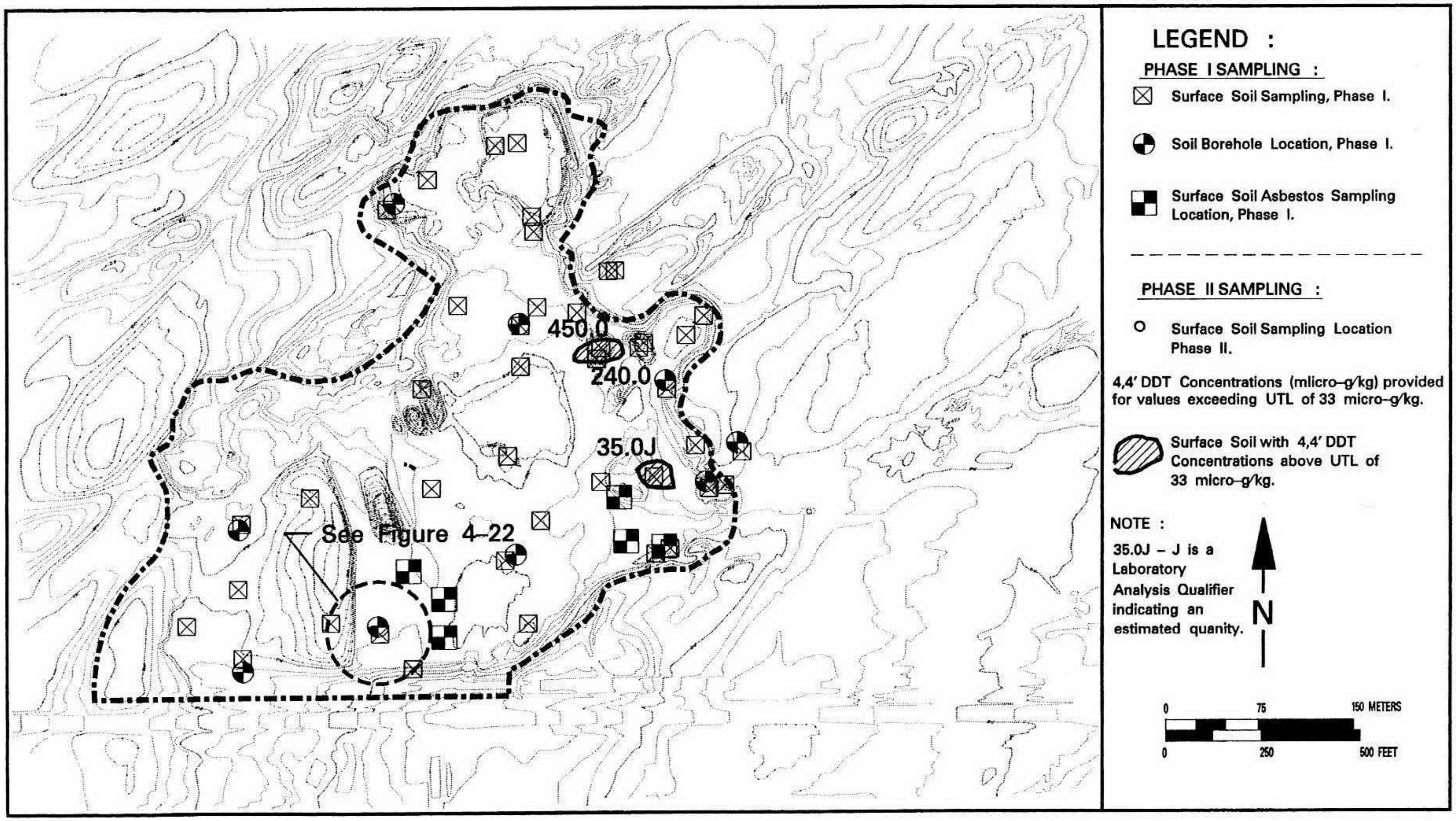
Horn Rapids Landfill – 4,4′ DDE Distribution in Surface soils.

Figure 4–20



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Horn Rapids Landfill – 4,4' DDT Distribution in Surface Soils.

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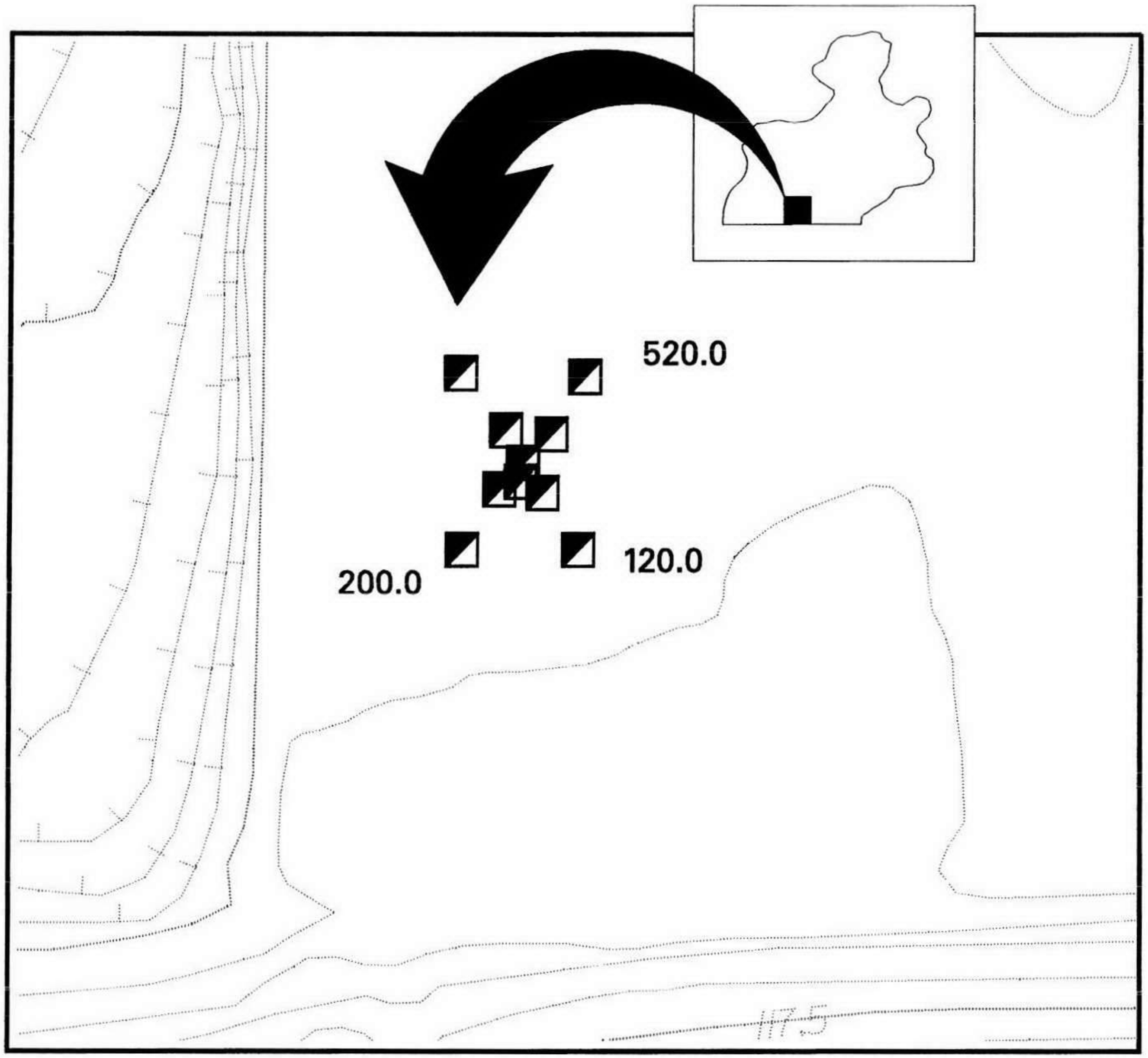
Figure 4-21



LEGEND :

Soil Sampling Location

4,4′ DDT Concentrations (micro–g/kg) for values exceeding UTL of 33 micro–g/kg. Maximum concentration shown for interval of 0 – 1.5 ft.

N

0 10 20 METERS

0 32.5 65 FEET

Contour interval is 0.5 meter.

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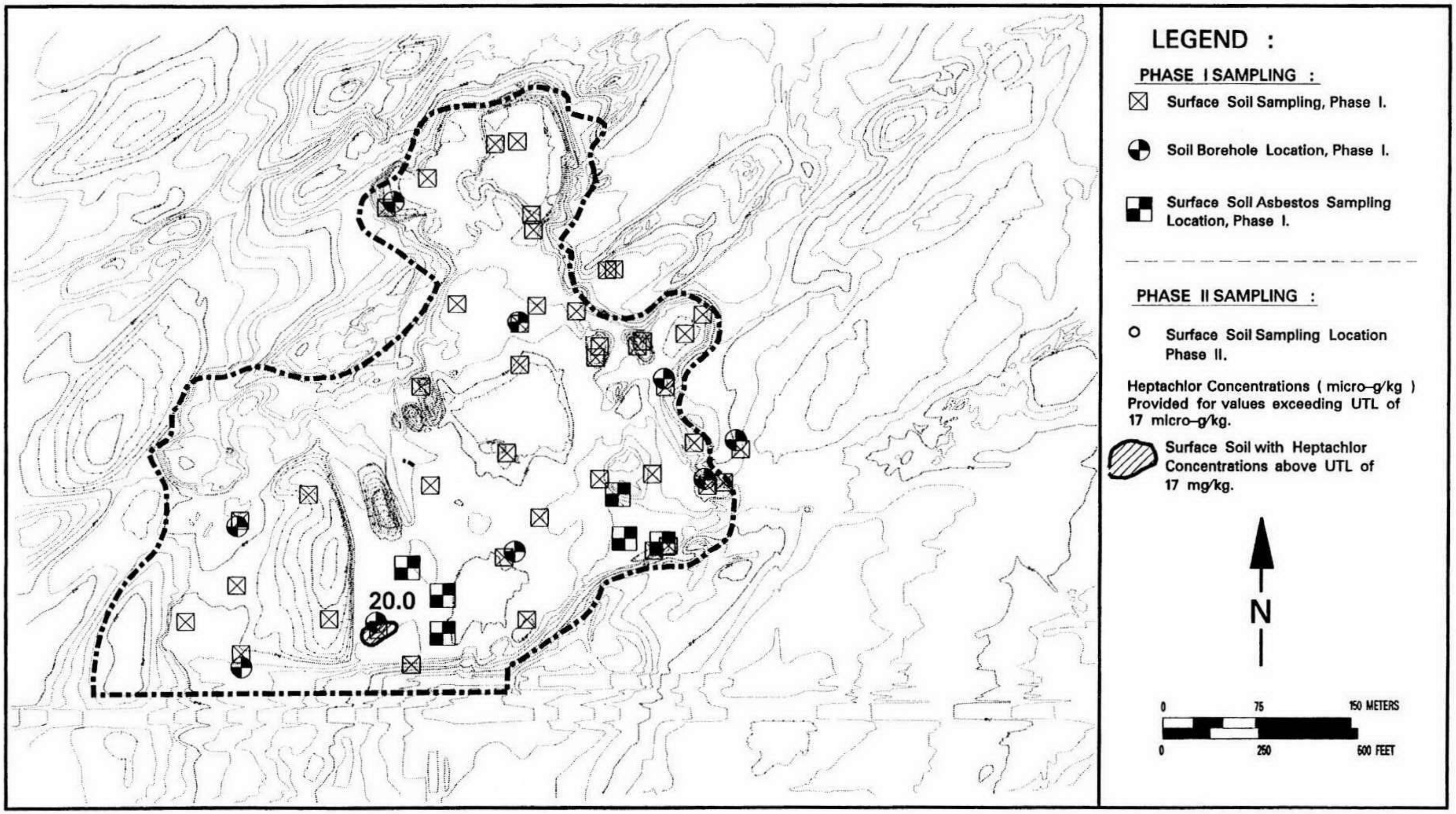
Horn Rapids Landfill – 4,4′ DDT Distribution in Surface Soils.

Figure 4–22



Contour interval is 0.5 meter.

Horn Rapids Landfill – Heptachlor Distribution in Surface Soils.

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Figure 4-23

4.7.1.16 PCB's. PCB contamination at concentrations exceeding UTL levels were detected in two surface samples collected during the Phase I investigation and in eight surface samples collected during the Phase II investigation. All 10 samples were collected in the same, very limited, area of the landfill (*i.e.*, adjacent to borehole HRL-4). Figure 4-24 shows the locations of Phase II samples having elevated PCB values. All PCB's detected in the surface soil were identified as aroclor-1248. One subsurface sample (sample A2205S from a depth interval of 1.6 to 2.4 m (5.4 to 8.0 ft) in borehole HRL-4) contained aroclor-1248 at a concentration exceeding the UTL limit. Aroclor-1254 was detected in one subsurface soil sample, collected from a depth of 2.7 m (9 ft) in exploration trench TP-1, at a concentration above the UTL.

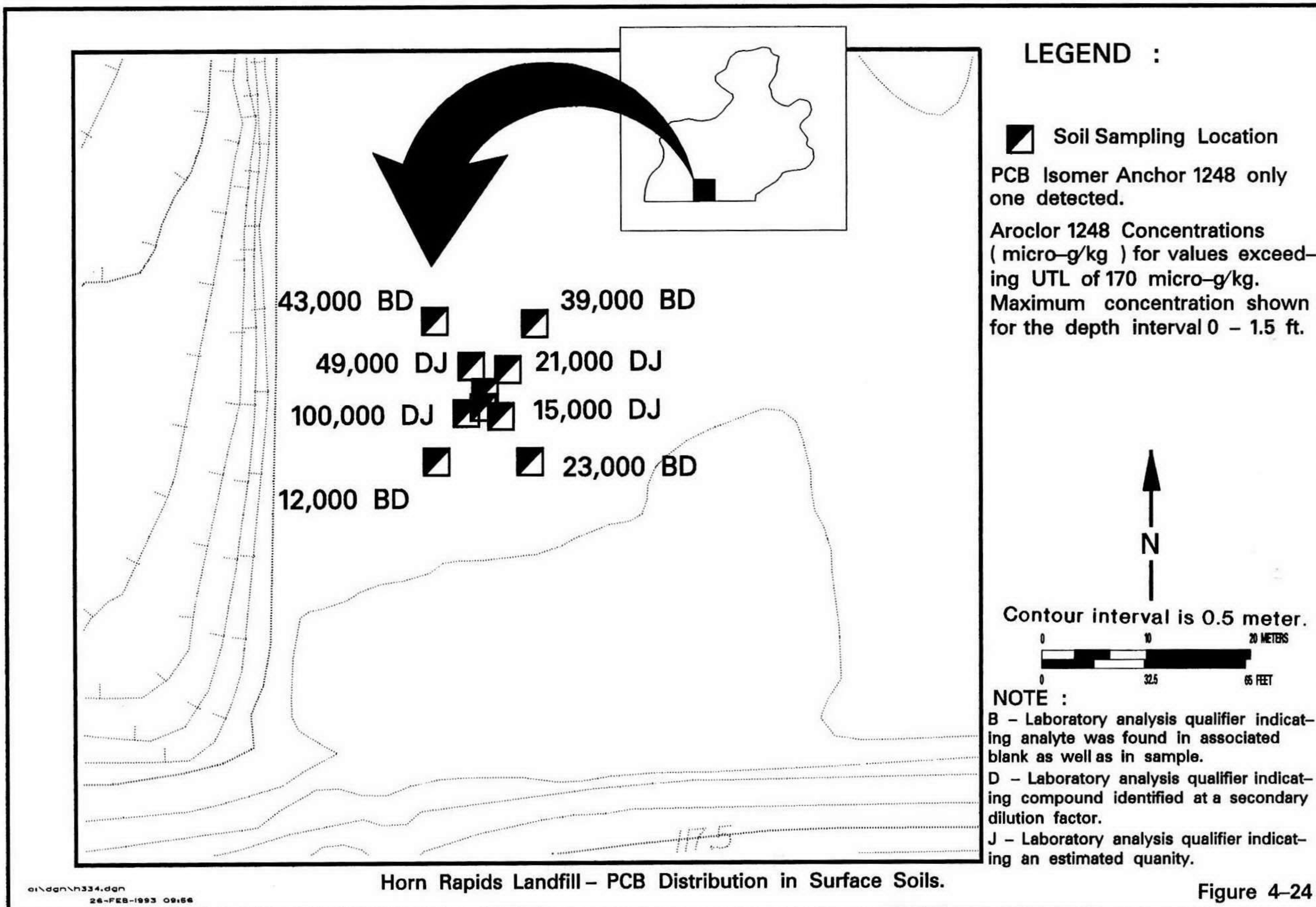
4.7.2 Groundwater

The extent of the TCE and nitrate plumes, identified in the Phase I RI, were further defined by new information concerning TCE and nitrate use at the SPC facilities and from additional data generated during the installation of new groundwater monitoring wells in the SPC/HRL area.

4.7.2.1 Source Information--TCE Plume. Information concerning the source of the TCE plume at the HRL/SPC area was provided by: (1) soil sampling, trenching investigations, geophysical surveys, and soil-gas investigations performed at the HRL and vicinity; (2) documents and reports provided by SPC; (3) groundwater sampling at SPC property; once in the fall of 1987, four times in 1990, three times in 1991, and quarterly in 1992; and (4) quarterly groundwater sampling, 1990 to present, of the 1100 Area monitoring wells.

The soil sampling, trenching investigations, geophysical surveys, and soil-gas investigations revealed no evidence of a TCE source in the vadose zone at HRL or the South Pit. The soil-gas measurements revealed the presence of TCE in the vadose zone at HRL and the South Pit, but at concentrations inconsistent with a significant free TCE source in the vadose zone at those locations (see paragraph 3.7). Siemens has indicated that soil sampling at the SPC facility did not identify the presence of a TCE source in the vadose zone (personal communication from Susan Kieth at 15 March 1993 Regulatory meeting). The details of the SPC soil sampling are to be published later in 1993.

The only documented record usage of TCE near the present-day contaminant plume was at the SPC lagoon area. The work plan for the hazardous substance source evaluation performed at SPC by Geraghty & Miller, Inc., identified the use of TCE at SPC during the installation of Hypalon™ lagoon liners (SPC, 1992). TCE was used to clean the liner in preparation for bonding overlapping liner sections together (meeting minutes, October 15 1990, meeting at the SPC, formerly Advanced Nuclear Fuels (ANF), facility). SPC also provided a liner installation, cleaning, and repair history that indicated that these activities started, for the Hypalon™ liners, in 1978 and continued through 1988 (as shown in figure 6-24). The most numerous liner installation and repair efforts occurred during three time periods around the years 1979, 1983, and 1987 to 1988.



Horn Rapids Landfill – PCB Distribution in Surface Soils.

Figure 4–24

Construction drawings for the SPC lagoons and the observed groundwater levels indicated that minimum distances from lagoon liners to the water table vary from 2.6 to 4.2 m (8.5 to 13.8 ft). The average depth to the water table at the SPC facility is about 4.6 m (15 ft). Construction drawings also indicated the material below the liners consists of a sand layer underlain by compacted fill material. TCE spilled or excessed during lagoon liner installation, cleaning, or repair would have a short and unobstructed pathway through the sand and fill material to groundwater.

Observed TCE levels in the groundwater at SPC are consistent with a source area located at the SPC facility. Furthermore, observed TCE levels in the groundwater at the down-gradient boundary of HRL are consistent with the introduction of TCE into the groundwater at the SPC facility between 1978 and 1988. No TCE has been detected in the groundwater up-gradient from the SPC facility (see table F-1). Only the sampling events during the period of TCE usage at SPC showed relatively high concentrations (at wells TW-1 and TW-9, located near the SPC lagoons). Subsequent sampling rounds showed that TCE levels dropped at these wells after usage of TCE was reportedly discontinued at SPC. The elevated TCE concentrations at HRL are directly down-gradient from the SPC lagoon area (groundwater potentiometric surface maps B-1 through B-19).

Site flow and transport parameter estimates indicate groundwater velocities sufficient to carry TCE from the SPC lagoon area to the HRL wells (MW-12 area), within the 1978-to-present timeframe. Three important parameters provide constraints on the range of movement of contaminants, specifically TCE, in the groundwater at the SPC/HRL area. These are hydraulic conductivity, the groundwater pressure gradient, and contaminant velocity retardation (the ratio of water velocity to contaminant velocity). Firstly, a reasonable range for the average hydraulic conductivity from the SPC lagoon area down-gradient to the MW-12 area was estimated to be 200 to 300 m/d (656 to 984 ft/d; see paragraph 2.4.3.2). This estimated range was based on aquifer pump tests and the geologic setting at the site. Secondly, the observed groundwater levels at wells TW-1 (near the SPC lagoons) and MW-12 (at the down-gradient HRL boundary) provide the average pressure gradient for the unconfined aquifer (approximately .0022 m/m). Thirdly, a TCE retardation factor range of 1.5 to 4.0 is typical for the types of low organic soils found at Hanford (DOE/RL-91-52; Mackay *et al.*, 1985), and a range of 1.2 to 2.4 was provided in the Phase I RI. A conservative (*e.g.*, slower) contaminant velocity estimate of 0.36 m/d (0.72 ft/d) was derived from the conservative bounds of the above ranges and a porosity of 0.30. Using this velocity, and a distance of 880 m (2900 ft), TCE potentially released at SPC in 1983 would move to the MW-12 area by 1990. This is consistent with the timeframe of TCE usage and elevated TCE levels observed at the MW-12 area. Groundwater flow and contaminant transport modeling was undertaken (see section 6) to more accurately define groundwater movement in the complex geologic setting, and predict contaminant transport.

A hypothesis of a source at HRL is not supported by the observed TCE levels. In order to attenuate to currently measured levels over the 20 years since landfill closure, a concentrated free source (at least in the 1000's ppb range) of sufficient mass would have had to have been present. The plume front from such a mass would move more than 2300 m (7500 ft) over the last 20 years, substantially beyond the wells near Stevens Drive. There have been no measurable TCE concentrations in these wells to date (*i.e.*, 699-S28-E12, 699-S29-E12, 699-S31-E13, 699-S32-E13A). The above contaminant velocity estimate uses 200 m/d hydraulic conductivity, average pressure gradient between MW-14 and S29-E12 of 0.00145 m/m, a retardation factor of 3.0 for the measurable plume front, and a porosity of 0.30.

The hypothesis of a continuous, or more recent, source of TCE in HRL is also not supported by the available data. Observed concentrations of TCE at HRL (maximums of 110 ppb in May 1990, and 58 in March 1992) are declining. If a significant continuous source were present, the TCE levels would be expected to remain roughly stable. Also, a significant continuous source would, over 20 years time, produce detectable TCE levels in the wells near Stevens Drive (based on the contaminant transport assumptions listed above). The continuous supply would tend to compensate for TCE lost to attenuation processes. The potential that a source was introduced at HRL sometime after its closure, and the potential for a "time release" source (a container at HRL that recently leaked TCE) cannot be entirely ruled out. Anecdotal information gathered in the Phase I RI suggested that up to 200 drums of an organic liquid (carbon tetrachloride) were deposited at HRL. This led to numerous geophysical surveys and extensive intrusive investigations, including trench excavations. No evidence of the barrels or other large containers was found at HRL. In addition, soil gas surveys found no evidence of a significant free source at HRL.

In summary, the current TCE levels at the HRL wells are consistent with: (1) the timeframe of TCE usage at SPC; (2) the groundwater flow direction from SPC to HRL; (3) the conservatively estimated contaminant transport velocities; and (4) the distance between the SPC lagoon area and the HRL wells. Observed TCE levels in site wells, and conservatively estimated velocities for the detectable contaminant plume front, do not support the supposition of a TCE source existing in HRL.

The potential for future releases of TCE from the SPC facility may be minimized because future lagoon repairs, relining, and construction are planned to be performed without use of TCE. TCE is not currently used in the nuclear fuel fabrication or process support operations at SPC (Bower, 1992). Maximum observed 1987 TCE concentrations at the SPC wells were about 15 times greater than the maximum observed 1992 levels, which are only about five times greater than the TCE MCL, suggesting a relatively short time until TCE concentrations drop below the MCL level at SPC.

The TCE data from SPC wells does not support the existence of a continuous source at SPC. Analysis of TCE groundwater sample concentrations over time indicated that the SPC levels are attenuating relatively quickly and that the contaminant is currently present at relatively low concentrations. A December 1987 sample from SPC well TW-9, located near the SPC lagoons, had a TCE concentration of 420 ppb while the average of two samples taken from the same well in 1991 was 12 ppb. The relatively rapid attenuation rate of TCE concentrations at this well indicates that the source for this TCE was not continuous. Concentrations at another SPC well, TW-1, showed similar attenuation from a December 1987 spike of 230 ppb to a 1991 level of 11 ppb. The observed attenuation of TCE is consistent with a low volume spike source rather than a continuous source.

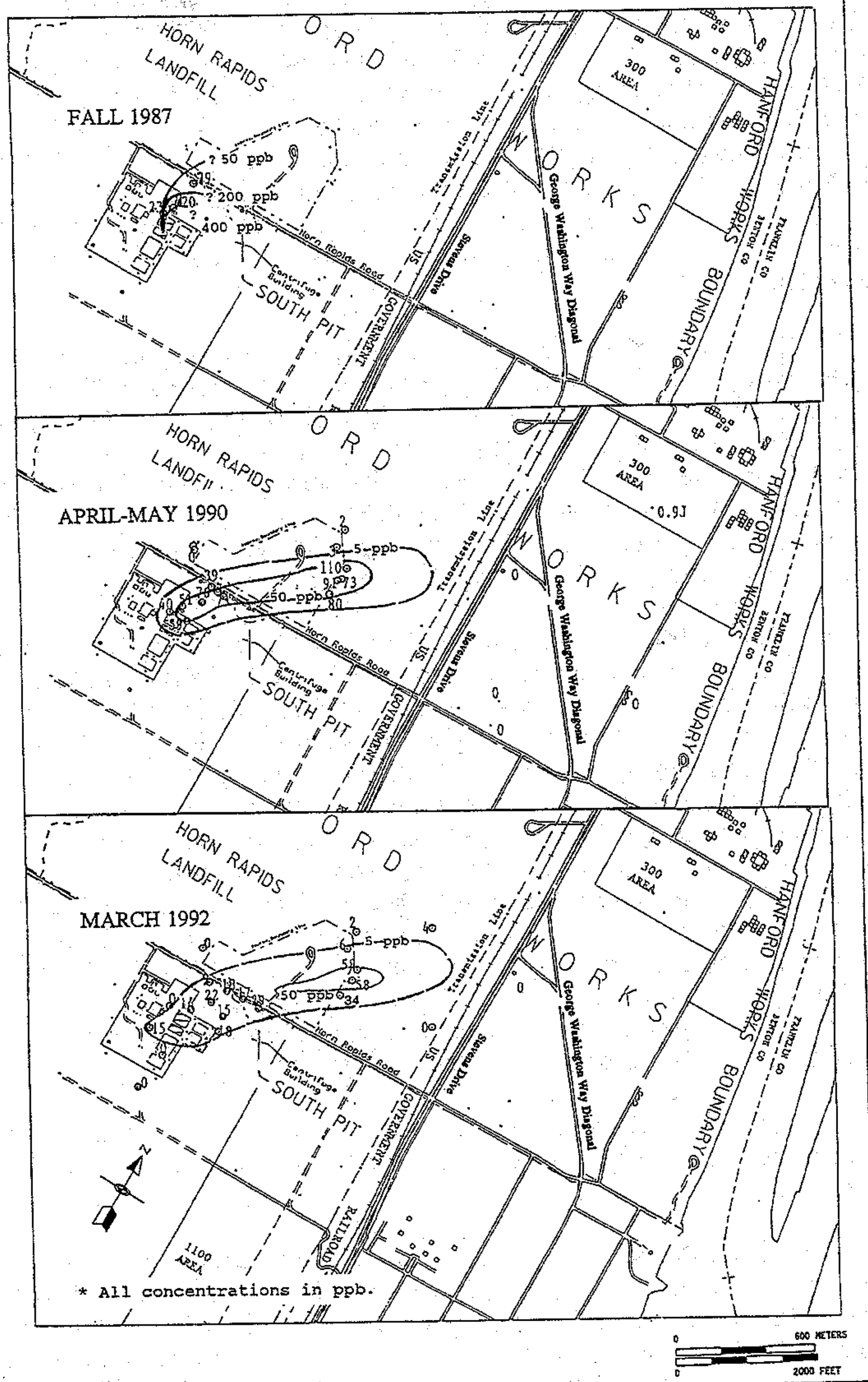
Similar attenuation is apparent in down-gradient wells located within the HRL. Well MW-12 had a concentration of 110 ppb in the spring of 1990 but was about one-half of that in the summer of 1992. This reduction is also consistent with that of an attenuating plume that originated from an up-gradient slug or spike source. However, estimated groundwater velocities are not sufficient to carry the December 1987 spike to MW-12 by 1990 (see previous discussion) suggesting earlier, up-gradient releases consistent with the timeframe of TCE use at SPC. Observed values tend to support the hypothesis of a series of releases over a period of time rather than a single release event. Detailed evaluation and modeling (see section 6.0) was undertaken to more formally analyze post-TCE usage and current conditions.

The amount of TCE in the groundwater, as indicated by measured monitoring well TCE concentrations and approximate plume dimensions, was about 75 to 110 L (20 to 30 gal) for the 1990 data, and about 57 to 83 L (15 to 22 gal) for the 1992 data (assumes 30 ft aquifer thickness, and .33 total porosity). Although an additional unknown amount is adsorbed onto the host soil, volatilized, biodegraded, or attenuated by other processes, the data indicate the total original amount of TCE source released to the ground was on the order of one to three drums. The total volume of groundwater within the TCE plume is approximately 132,000 cubic meters (m^3) (0.5 billion gal).

4.7.2.2 Source Information - Nitrate Plume. Information on potential nitrate sources was provided by groundwater sampling results from the SPC and HRL areas, and from SPC documents. The earliest data from the 1970's indicate maximum total nitrogen (NH_3 + NO_3) levels of 400 ppm, 1800 ppm, 300 ppm, and 300 ppm in SPC wells TW-1, TW-2, TW-3, and TW-9, respectively (Exxon Nuclear Company, Inc., 1982). This data was not directly used in this analysis because the nitrate-to-total-nitrogen ratio was not known; but even at low ratios, the nitrogen levels would be much higher than the 10 ppm MCL. Nitrogen was specifically included as a measurement parameter in groundwater sample analyses beginning in 1981, with detected levels consistently between 20 and 100 ppm in the SPC area down-gradient of the lagoons and facilities. Nitrate values upgradient of the SPC facilities and lagoons have been below 10 ppm (measured at TW-23, TW-24, GM-1, and GM-2). SPC's hazardous substance source evaluation work plan identifies at least eight areas of potential nitrate releases from the SPC facility including the lagoons, the Ammonia Recovery Facility (ARF), former tank farms, storage areas, *etc.* (SPC, 1992).

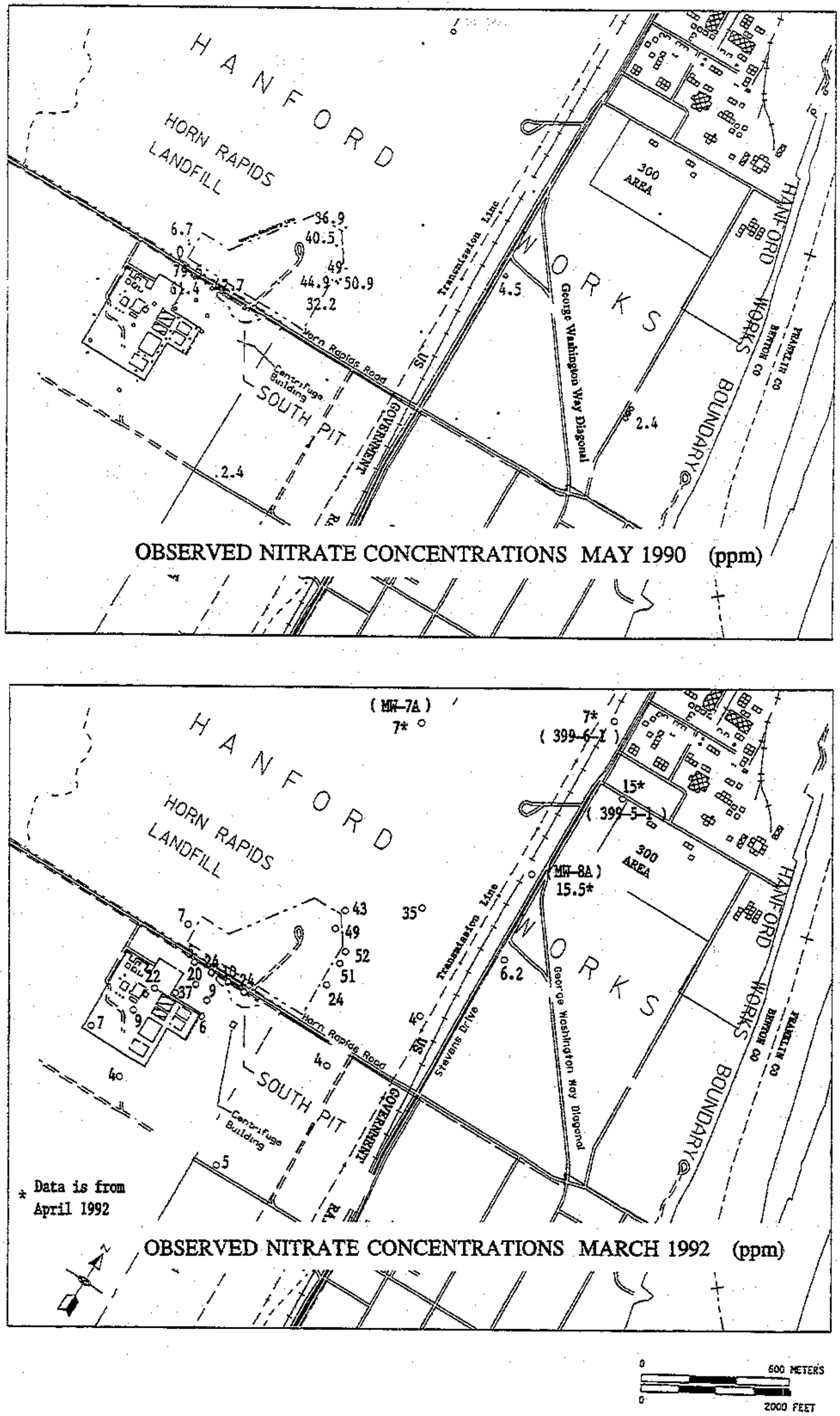
The potential for a nitrate source in HRL cannot be entirely ruled out but, like TCE, the location and concentrations observed at HRL are consistent with the migration of nitrate from SPC to HRL.

4.7.2.3 Plume Delineations. TCE and nitrate contaminants were found only in the unconfined aquifer. The approximate horizontal distributions of TCE and nitrate at the HRL/SPC for the 1987 to 1992 period are shown in figures 4-25 and 4-26. Values from interim sampling events not shown on the figures were consistent with the trend of the indicated values, and can be found in appendixes E and F. The TCE plume extends in the direction consistent with groundwater flow, with its up-gradient end identifying the approximate source area. The earliest TCE data available, from the fall of 1987, consists of three measurements taken near the SPC lagoons. The highest of these, 420 ppb at well



Observed TCE Concentration Levels from 1987 to 1992 and Approximate Plume Delineations.

Figure 4-25



Observed Nitrate Concentration Levels in 1990 and 1992.

Figure 4-26

TW-9, is about 40 times higher than concentrations at that same well in 1992, and is over 8 times higher than the highest concentration observed in the plume in 1992. This suggests considerable natural attenuation of site concentration levels, and is consistent with a low-volume, non-continuous source.

Trends in TCE levels show attenuation of TCE concentrations across the site. Figure 4-27 shows the trend of TCE concentration levels over time for five representative wells within the plume. TW-1 and TW-9 are located at the up-gradient end (SPC area), TW-15 is located near Horn Rapids Road, and MW-12 and MW-15 are located at the down-gradient boundary of the HRL (figure 6-13 shows well locations). TW-1 and TW-9 concentrations were relatively high in 1987 but decreased relatively rapidly thereafter. Down-gradient concentrations were lower and also showed significant reduction over time. These data sets show a general decrease in concentrations throughout the identified plume. As previously discussed, estimates of the amount of TCE in the groundwater ranged from 75 to 110 L (20 to 30 gal) for the 1990 data, and about 57 to 83 L (15 to 22 gal) for the 1992 data. The data points in figure 4-27 were connected by cubic curvilinear regression lines that were provided to assist the viewer in connecting the data from the five different wells but were not intended to represent exact values between the actual data points. However, curvilinear regression was used instead of simple straight-line interpolation because attenuation processes are nonlinear.

The first groundwater samples to be analyzed for TCE at the HRL were taken in early 1990 and revealed maximum concentrations of 110 ppb (at MW-12). Subsequent quarterly sampling showed concentrations to be steadily decreasing through the latest sampling rounds, which occurred in 1992. Concentration levels detected in 1992 at MW-12 are nearly half that of the 1990 levels. If this "attenuation" rate were to continue, using a target level of 5 ppb, the TCE concentrations would be reduced to below the MCL by the year 2000. This simple extrapolation does not account for plume movement or other relevant factors (see paragraph 6.4.1). This attenuation may be due to dispersion (*i.e.*, mixing and spreading) resulting from the high hydraulic conductivities in the upper soil strata at the site. Biodegradation and volatilization may also account for some of the attenuation. More detailed discussion on contaminant fate and transport are found in the contaminant transport and modeling section (paragraph 6.4).

Review of existing data, from 1987 through 1992, did not allow determination, by direct observation, of the rate of movement of the plume front because of the long distances between observation wells down-gradient of HRL. There exists some uncertainty about the TCE measurements from well 699-S29-E12, because it is screened over a larger interval than the other 1100-EM-1 wells. A difference in well construction does not mean that the sampling data from this well is not representative. It has been speculated that water drawn from this well during sampling contains a larger proportion of water from the lower portions of the aquifer, potentially diluting samples. Additional monitoring wells, to be located in this area, have been recommended for later project phases.

Nitrate data from May 1990 and March 1992 are shown in figure 4-26. Interim sampling is consistent with the sampling rounds shown. The direction of plume elongation is consistent with the direction of groundwater flow, with the up-gradient end indicating the approximate source area. A comparison of the 1990 and 1992 data sets indicates that nitrate levels in the SPC area have generally decreased by about one-half, while levels near the MW-12 well cluster have stayed about the same over this short time period. The highest concentration levels of nitrate (1,800 ppm, measured as total nitrogen), were observed in the 1970's at TW-2 at the SPC facility (Exxon Nuclear Company, Inc., 1982). The concentrations observed at the MW-12 area are currently in the 50 ppm range.

Quarterly sampling of 300 Area wells, beginning in 1991, indicates elevated nitrate levels in the southwest part of the 300 Area. The nitrate levels for the April 1992 round are shown on figure 4-26, and were obtained informally from 300 Area project management personnel. The available data from prior and subsequent sampling shows similar levels. This data suggests that the nitrate plume from the SPC/HRL area extends into the 300 Area. However, the available data is not adequate to define the plume. Using data from 300 Area well MW-7A to define an HRL/SPC plume is inappropriate at this time, because this well does not appear to be down-gradient of the HRL/SPC area. It is not unlikely that the nitrate in this well, and potentially in wells 399-6-1 and 399-5-1, originated west or northwest of the 300 Area. More appropriately, the exact definition of the nitrate plume is not essential to this RI/FS because (as will be discussed in following sections of this report) remediation, solely for nitrate, is not likely to be required due to its relatively low concentration levels. Ongoing sampling, coordinated with Hanford sampling outside the 1100 Area, will provide further definition of the nitrate plume.

The vertical distribution of contaminants within the unconfined aquifer is not definable, because the sampling wells are consistently screened over the same interval. Without discreet screens set at different elevations within the upper aquifer, no data were available for determining a vertical distribution. However, research on the migration of chlorinated hydrocarbons in porous media indicate that, at low concentrations (the HRL concentrations would be considered very low), differences in densities between the contaminant and the host water do not cause the plume to sink and the influence of the kinetic forces (water momentum forces) will be far greater than the gravitational forces (differences in densities) (Schwille, 1988). The exception occurs when a free, dense, non-aqueous phase of the contaminant exists. Such an occurrence would be indicated by groundwater concentrations in the 1000's or 10,000's ppm, which is three orders of magnitude higher than concentrations measured within the HRL/SPC area. Based on published research and observed concentration levels, the TCE plume in the HRL/SPC area is expected to be distributed evenly in the vertical direction throughout the unconfined aquifer. There have been no contaminants detected in groundwater samples obtained from the confined aquifer at concentrations above UTL's.

4.8 SUMMARY OF NATURE AND EXTENT OF CONTAMINATION

Seven subunits within the 1100-EM-1 Operable Unit have detectable soil contamination at concentrations above preliminary risk-based screening levels. These contaminants are summarized in table 4-8. Contaminants above preliminary risk-based screening levels in groundwater samples obtained from the unconfined aquifer to be considered during the risk assessment for the 1100-EM-1 Operable Unit include TCE and nitrate. In section 5.0, these contaminants, in both the soil and the groundwater, are further evaluated in a more rigorous and extensive risk assessment process to identify a list of contaminants of concern to be addressed in the remediation of the 1100-EM-1 Operable Unit.

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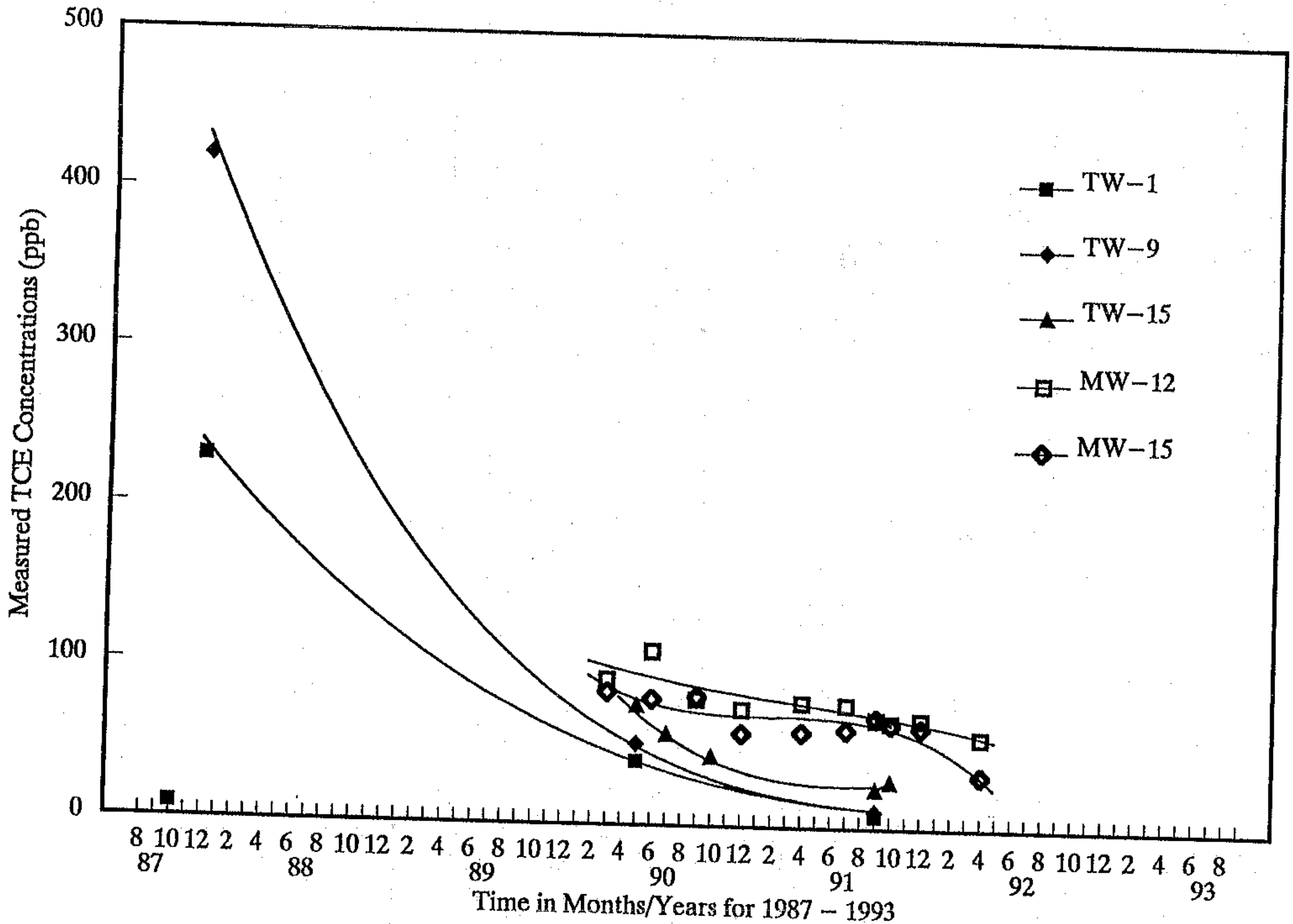

Trends of TCE Concentration Levels at the SPC/HRL Area.
Figure 4-27

Table 4-8. Summary of Contaminants of Potential Concern for the 1100-EM1 Operable Unit.

Contaminant	1100-1	1100-2	1100-3	1100-4	UN-1100-6	Horn Rapids Landfill	Ephemeral Pool	Ground-water
Antimony						X		
Arsenic	X		X	X		X		
Barium						X		
Beryllium			X	X		X		
Chromium		X	X			X		
Copper						X		
Lead[a]								
Manganese		X	X			X		
Nickel	X					X		
Thallium						X		
Vanadium	X					X		
Zinc						X		
BEHP					X			
Beta-HCH						X		
Chlordane					X		X	
DDT						X		
Heptachlor					X	X	X	
PCBs						X	X	
Nitrate								X
TCE								X

[a]Contaminant of interest

Table 4-8
Page 1 of 1

5.0 CONTAMINANTS OF CONCERN

The contaminants of concern were identified through the baseline risk assessment process. Note: The screening of contaminants for the baseline risk assessments did not strictly follow EPA Region 10 guidance but an interpretation of the HSBRAM. The exclusion of organic contaminants was done without going through the full prescreening process. The HSBRAM is currently being revised to prevent such an interpretation in the future. Summaries of the risk assessments are presented in paragraphs 5.1, 5.2, and 5.3. Complete Risk Assessments can be found in appendixes K and L of this RI/FS. The contaminants of concern were derived from the soil contaminants assessed in the industrial scenario and groundwater contaminants assessed in the residential scenario. The contaminants of concern are:

- Arsenic
- Chlordane
- Trichloroethene
- BEHP
- Nitrate
- Beryllium
- Chromium
- PCB's

The toxicity profiles of these contaminants are contained in appendix K. The risk from these contaminants are summarized in tables 5-1 and 5-2.

5.1 SUMMARY OF BASELINE INDUSTRIAL SCENARIO RISK ASSESSMENT

The baseline industrial scenario risk assessment (BISRA) was conducted according to Hanford Site Baseline Risk Assessment Methodology (HSBRAM) (DOE/RL-91-45). The HSBRAM was developed using EPA Region 10 guidance. Contaminants were determined by comparing maximum detected concentrations of parameters to the UTL values for that parameter. The contaminants of potential concern derived from this comparison were presented in table 4-9.

The contaminants were evaluated in a two step process to minimize statistical analyses and allow health risk based comparison of maximum value concentrations and 95-percent upper confidence limit (UCL) concentrations. Maximum concentrations were used not only for preliminary risk based screening but also for the initial risk based assessment calculations. If a health risk was indicated using maximum concentration, then the 95-percent UCL concentration was used to refine quantification of the health risk.

The maximum concentrations of contaminants of potential concern detected within each subunit were evaluated for each subunit. Conservative assumptions were made with respect to the contaminants present. For three subunits, UN-1100-6 (Discolored Soil Site), the Ephermeral Pool, and HRL, soil contaminants that were estimated to have an Incremental Cancer Risk (ICR) greater than 1E-06, based on the maximum dected contaminant concentrations, were evaluated using a 95-percent UCL concentration.

The exposure pathways for the industrial were defined in the HSBRAM (DOE/RL-91-45). These are conservative default parameters for a generic industrial worker. The BISRA evaluated only pathways associated with exposure to soils (*i.e.*, soil ingestion, dermal

Table 5-1. Summary of the Risks Derived from Contaminants of Concern for Soil Contaminants Based on the 95-percent UCL for Discolored Soil Site (UN-1100-6), the Ephermeral Pool, and the Horn Rapids Landfill.

Contaminant	Pathway						Contaminant Totals		Subunit Totals	
	Soil Ingestion		Fugitive Dust Inhalation		Dermal Exposure					
	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[c]	ICR[b]
UN-1100-6										
BEHP	0.3	2E-05	--	2E-08	0.03	2E-06	0.3	2E-05		
Chlordane	0.008	2E-07	--	2E-10	0.009	2E-07	0.01	4E-07		
Pathway Totals	0.3	2E-05	--	2E-08	0.04	2E-06			0.3	2E-05
Ephemeral Pool										
Chlordane	0.009	2E-07	--	6E-10	0.01	2E-07	0.02	4E-07		
PCBs	--	9E-06	--	3E-08	--	1E-05	--	2E-05		
Pathway Totals	0.009	9E-06	--	3E-08	0.01	1E-05			0.02	2E-05
Horn Rapids Landfill										
Arsenic	0.001	2E-07	--	1E-08	0.00003	4E-09	0.001	2E-07		
Chromium	0.005	--	--	2E-06	0.00009	--	0.005	2E-06		
PCBs	--	2E-05	--	2E-07	--	3E-05	--	5E-05		
Pathway Totals	0.007	2E-05	--	2E-06	0.0001	3E-05			0.007	5E-05

[a]Hazard Quotient
[b]Lifetime Incremental Cancer Risk
[c]Hazard Index
[d]Based on 30% absorption of inhaled arsenic (EPA 1992b)
-- = Not Applicable

Table 5-2. Summary of Risk Derived from Groundwater Based on the 95-percent UCL Concentrations from the Baseline Residential Scenario Risk Assessment

Contaminant	Pathway			
	Groundwater Ingestion		Groundwater Inhalation	
	HQ[a]	ICR[b]	HQ[a]	ICR[b]
Nitrate	0.8	--[c]	--[d]	--[c,d]
Trichloroethene	--[e]	1E-05	--[e]	2E-05

[a]Hazard Quotient
[b]Lifetime Incremental Cancer Risk
[c]Not considered to be a carcinogen
[d]Not a volatile contaminant
[e]RfD not available to evaluate this pathway
UCL = Upper Confidence Level
-- Indicates not applicable

9 3 1 2 9 3 3 0 2 8 0

exposure to soil, and fugitive dust inhalation). Potential exposures associated with groundwater and surface water were not evaluated in this BISRA. Neither groundwater nor surfacewater is withdrawn from the 1100 Area. Potable water is provided by the city of Richland. The air inhalation pathway assumes exposure to windblown contaminants in dust directly from each subunit. The EPA Fugitive Dust Model (FDM) was used to estimate concentrations of airborne particulates at each site based on conservative estimation of soil and climatic conditions. Chromium present in the soil at HRL was the only contaminant that may be associated with risks greater than 1E-06. However, all chromium was assumed to be hexavalent chromium which is a conservative assumption and unlikely to be representative of the true valence states present. Hexavalent chromium under aerobic conditions is reduced to trivalent chromium. Adverse effects have not been associated with the trivalent chromium form.

Evaluation of the potential contaminants of concern using the maximum and 95-percent UCL's identified the contaminants of concern for the individual subunits in the 1100-EM-1. Contaminants of concern for individual subunits as determined in the BISRA are:

UN-1100-6 (Discolored Soil Site)
- BEHP

Ephemeral Pool
- PCB's

HRL
- Chromium
- PCB's

A summary of the industrial scenario risk assessment based on the 95-percent UCL for UN-1100-6 (Discolored Soil Site), Ephemeral Pool, and HRL is presented in table 5-3.

Chromium was identified as a contaminant of concern at HRL due to the fugitive dust exposure pathway. This determination was made using maximum and 95-percent UCL soil chromium concentrations taken at depths from 0 to 4.6 m (0-15 ft) in selected boreholes and exploratory trenches. Using these values in risk based screening within the risk assessment is appropriate. However, remedial actions to protect the ambient air quality from contaminated fugitive dust migration should specifically apply to surface soils. Upon reevaluating sample analyses from chromium in only the top 0.6 m (2 ft) of HRL, a mean concentration for chromium in soils of 9.06 mg/kg with a 95-percent UCL of 9.76 mg/kg was calculated. The Phase I RI reported chromium in background soils with a mean concentration of 9.19 mg/kg and a 95-percent UTL of 12.9 mg/kg providing evidence that chromium concentrations in the HRL surface soils are typical of the site. Using the 95-percent UCL of 9.76 mg/kg to recalculate the incremental cancer risk of fugitive dust from the HRL gives a risk of 2E-7 under the industrial scenario. Therefore, chromium is determined not to be a contaminant of concern and will not be considered when developing remedial alternatives.

Table 5-3. Comparison of the Baseline Industrial Incremental Cancer Risk Assessment Results using the Maximum Contaminant Concentrations and 95-percent UCL for Discolored Soil Site (UN-1100-6), the Ephemeral Pool, and the Horn Rapids Landfill.

Subunit	Pathway	95% UCL Pathway Totals	Maximum Concentration Pathway Totals	95% UCL Subunit Totals	Maximum Concentration Subunit Totals
		ICR	ICR	ICR	ICR
UN-1100-6	Soil Ingestion	2E-05	3E-05		
	Fugitive Dust Inhalation	2E-08	3E-08		
	Dermal Exposure	2E-06	3E-06		
				2E-05	3E-05
Ephemeral Pool	Soil Ingestion	9E-06	3E-05		
	Fugitive Dust Inhalation	3E-08	8E-08		
	Dermal Exposure	1E-05	3E-05		
				2E-05	6E-05
Horn Rapids Landfill	Soil Ingestion	2E-05	6E-05		
	Fugitive Dust Inhalation	2E-06	3E-05		
	Dermal Exposure	3E-05	8E-05		
				5E-05	2E-04

5.2 SUMMARY OF BASELINE RESIDENTIAL SCENARIO RISK ASSESSMENT

The BRSRA was conducted to fulfill an agreement made between DOE-RL, EPA, and Ecology. The scope of the BRSRA was defined by an EPA letter [Einan,1991 (see appendix K)]. Further discussion and correspondence is contained in appendix K.

Based on the results of the Phase I RI Report, EPA selected the following contaminants of potential concern, and these were evaluated in the BRSRA:

1100-2 (Paint and Solvent Pit)	Tetrachloroethene
1100-3 (Antifreeze and Degreaser Pit)	Arsenic Chromium Lead
UN-1100-6 (Discolored Soil Site)	Bis (2-ethylhexyl) phthalate (BEHP) Chlordane
HRL	Arsenic Chromium PCB's Nitrate Tetrachlorethene Trichloroethene 1,1,1-Trichloroethane Lead
Ephemeral Pool	Chlordane PCB's

In addition to the above, beryllium was evaluated as a contaminant of potential concern at HRL because the Slope Factor was not available when the Phase I RI Report was prepared.

The contaminants were evaluated in a two step process to minimize statistical analyses and allow comparison of maximum value concentrations and 95-percent UCL concentrations.

The BRSRA evaluates pathways defined by EPA and focused on soil and water. The soil related pathways included ingestion of soil, dermal contact with soil, ingestion of garden produce, and inhalation of particulates. The air inhalation pathway assumes exposure to concentrations of dust directly from each subunit. The FDM is used to estimate concentrations of airborne particulate at a site based on conservative estimations of soil and climatic conditions. Region 10 default parameters for residential scenario are used (see appendix K). Chromium and PCB's present in the soil at HRL are the only contaminant that may be associated with risks greater than 1E-06. However, all chromium is assumed to be chromium(VI), which is a conservative assumption.

The EPA specified exposure pathways for groundwater contaminants detected in the vicinity of HRL include: ingestion of groundwater, inhalation of volatiles from groundwater, ingestion of Columbia River fish, and dermal contact with Columbia River water during swimming.

Evaluation of the potential contaminants of concern using the maximum and 95-percent UCL identified the contaminants of concern for the individual subunits in the 1100-EM-1. Contaminants of concern for individual subunits as determined in the BRSRA are:

UN-1100-3
- Arsenic

UN-1100-6 (Discolored Soil Site)
- BEHP
- Chlordane

Ephemeral Pool
- Chlordane
- PCB's

HRL
- Arsenic
- Beryllium
- Chromium
- Nitrate
- PCB's
- TCE

A summary of residential scenario risk assessment based on the 95-percent UCL for UN-1100-6 (Discolored Soil Site), Ephemeral Pool, and HRL is presented in table 5-4.

5.3 SUMMARY OF ECOLOGICAL RISK ASSESSMENT FOR THE 1100-EM-1 OPERABLE UNIT

5.3.1 Purpose and Scope of the Ecological Risk Assessment

The objective of the Ecological Risk Assessment is to provide an evaluation of the site specific ecological risks. An Environmental Assessment was provided in the Phase I RI report (DOE/RL-90-18) for the 1100-EM-1 Operable Unit. Presentation of an ecological risk assessment for the Phase II RI/FS is a voluntary effort that includes Phase II RI data in a manner that follows guidelines outlined in the HSBRAM (DOE/RL-91-45).

This Ecological Risk Assessment includes a problem definition, analysis, and risk characterization. The problem definition identified stressor characteristics (*i.e.*, COPC),

Table 5-4. Comparison of the Baseline Residential Scenario Risk Assessment Results using the Maximum Contaminant Concentrations and 95-percent UCL for Discolored Soil Site (UN-1100-6), the Ephemeral Pool, and the Horn Rapids Landfill.

Subunit	Pathway	95% UCL Pathway Totals		Maximum Concentration Pathway Totals		95% UCL Subunit Totals		Maximum Concentration Subunit Totals	
		HI[a]	ICR[b]	HI[a]	ICR[b]	HI[a]	ICR[b]	HI[a]	ICR[b]
UN-1100-6	Soil Ingestion	3.0	4E-04	4.7	6E-04				
	Fugitive Dust Inhalation	--	5E-08	--	7E-08				
	Dermal Exposure	0.5	5E-05	0.7	8E-05				
	Garden Produce	15	2E-03	18	2E-03				
						18	2E-03	23	3E-03
Ephemeral Pool	Soil Ingestion	0.1	2E-04	0.2	5E-04				
	Fugitive Dust Inhalation	--	6E-08	--	2E-07				
	Dermal Exposure	0.2	2E-04	0.2	7E-04				
	Garden Produce	2.2	8E-04	3.2	2E-03				
						2.5	1E-03	3.6	3E-03
Horn Rapids Landfill	Soil Ingestion	0.08	5E-04	1	1E-03				
	Fugitive Dust Inhalation	--	4E-06	--	6E-05				
	Dermal Exposure	0.001	6E-04	0.02	2E-03				
	Garden Produce	0.3	2E-03	3.6	4E-03				
	Groundwater Ingestion	0.8	1E-05	1	1E-05				
	Inhalation of Volatiles from Groundwater	--	2E-05	--	3E-05				
						1.2	3E-03	5.6	7E-03

[a]Hazard Index
[b]Lifetime Incremental Cancer Risk
UCL Upper Confidence Limit
-- Indicates not applicable

ecosystems potentially at risk and ecological effects. These discussions lead to the selection of assessment and measurement endpoints. Assessment endpoints are those "specific properties of each habitat of interest used to evaluate the state, or change in the state, of the ecological system" (DOE/RL-91-45). Measurement endpoints are "those used to approximate, represent or lead to an assessment endpoint" (DOE/RL-91-45). An analysis was performed by characterizing exposure and ecological effects. Risk characterization was performed by integrating exposure and toxicity, discussing uncertainty, and interpreting ecological risk.

5.3.2 Problem Definition

The problem definition involved identifying ecosystems potentially at risk, the stressor characteristics, ecological effects, and the selection of assessment and measurement endpoints. Potentially sensitive habitats chosen for the 1100-EM-1 site include habitats known to be frequented by designated or proposed, endangered or threatened species. In determining ecosystems potentially at risk at 1100 EM-1, only terrestrial organisms are considered. Aquatic species are not addressed, since it has been demonstrated through groundwater modeling that contaminants in the groundwater will not likely reach the river above drinking water standards.

The dominant plant species within the 1100 Area are sagebrush-bitterbrush and cheatgrass. The sandwort is designated a monitor species (DNR, 1990). Table L-1 (appendix L) is a list of mammals, birds, reptiles and insects that may inhabit the 1100 Area. Of the birds listed, the peregrine falcon and ferruginous hawk are endangered and threatened, respectively. The Swainson's hawk, golden eagle, and prairie falcon are candidate species and the long-billed curlew is a monitored species. No threatened or endangered species of mammals, reptiles, or insects are known to inhabit the 1100 Area. However, the grasshopper mouse and sagebrush vole are monitored, and the pocket gopher and striped whipsnake are candidate species.

No toxicological studies were performed on species inhabiting 1100-EM-1 for the Phase I or Phase II RIs. The toxicological effects on species exposed to the COPC are assumed to be those addressed in the derivation of parameters such as the No Observed Adverse Effect Level (NOAEL). These parameters are used in the analysis and characterization sections.

Phase I field observations of the ecology of 1100-EM-1 (DOE/RL-91-18) showed that there was no evidence of adverse impacts from the COPC to the flora and fauna inhabiting any of the subunits, except for the UN-1100-6 (Discolored Soil Site). Except for a single clump of grass, there is no vegetation growing in the depression of the UN-1100-6 subunit (Discolored Soil Site). The only evidence of ecological damage at the operable unit is this apparent lack of vegetative growth at this subunit.

As noted above, assessment endpoints are the properties of habitats of potential concern that are used to assess the state of an ecosystem. These endpoints "must be of ecological importance and of direct management relevance..." (DOE/RL-91-45).

Terrestrial organisms have been designated as having habitats of potential concern for this site and the ferruginous hawk and peregrine falcon are threatened and endangered, respectively. From these considerations, adverse effects on these raptors have been chosen as assessment endpoints in this risk assessment. Without better data, it isn't possible to be more specific about the assessment endpoints (*i.e.*, to specify, for example, abundance, mortality, or ecosystem productive capability).

A measurement endpoint is defined "to approximate, represent or lead to an assessment endpoint" (DOE/RL-91-45). For this risk assessment, adverse effects on the swainson's hawk and long-billed curlew were used as measurement endpoints. These birds were chosen since they can be considered analog species. Since the Swainson's hawk and long-billed curlew have been designated as candidate and monitored species, respectively, data for the exposure assessments were readily available.

5.3.3 Analysis

The analysis involved performing an exposure and toxicity assessment. This involved first identifying the exposure pathways and secondly, calculating intake rates for the receptor population (Swainson's hawk and long-billed curlew).

COPC uptake calculations for the Swainson's hawk and long-billed curlew were performed according to Risk Assessment Guidance for Superfund (EPA, 1989a). In appendix L, table L-2 lists maximum contaminant concentrations and plant and small mammal uptake factors used in uptake calculations. Similarly, the results of the uptake calculations are reported in table L-3. Appropriate parameters were not always available, so conservative estimations, taken from previously conducted studies, were made whenever necessary.

Intake rates for the analog species (Swainson's hawk and long-billed curlew) were compared to toxicological values in appendix L, table L-4. Values for birds were used whenever possible. When these rates were not available, values for small mammals were reported. The most conservative parameters were used where available [*e.g.*, NOAEL as opposed to the Lowest Observed Adverse Effect Level (LOAEL)].

5.3.4 Risk Characterization

Given the uncertainty in information available, it was not practical to perform risk calculations for this evaluation. Ecological risk was estimated by comparing exposure to the contaminant toxicity.

None of the uptake rates in table L-2 exceed the toxicologic values in table L-3. For the Swainson's hawk, uptake rates for zinc, BEHP, beta-Hexachlorocyclohexane (β-HCH), 1,1,1--trichloro-2, 2-bis(p-chlorophenyl)ethane (DDT), and PCB were between 10 and 80 times lower than the corresponding toxicity value. Uptake rates for copper, thallium, and chlordane were between 2,000 and 20,000 times lower, and the remaining uptake rates were more than 300,000 times below toxicity values. For the long-billed curlew, arsenic, barium, nickel, vanadium, zinc, and BEHP had uptake rates 20 to 100 times less than toxicity values. The other contaminants were more than 100 times less than toxicity values.

5.3.5 Uncertainty Analysis

There were many sources of uncertainty in the exposure assessment and risk characterization for the ecological evaluation of 1100-EM-1. All information regarding the presence and behavior of species at the site, the exposure to contaminants, and toxicity of contaminants was estimated and extrapolated from information available from previous studies. Limited ecological data were taken from the site, therefore, the most conservative and simple models were used to determine the ecological impact. Thus, the exposure assessment represents the worst case scenario and the comparison of toxicity to exposure was highly conservative.

Since limited field observations were made, a search was performed to identify all terrestrial organisms expected to inhabit the Hanford site. Organisms that seemed likely to exist at 1100-EM-1 were reported in table L-1. This list excluded organisms, such as amphibians, not likely to be found at 1100-EM-1. It is probable that many of the organisms listed in table L-1 do not actually inhabit the site, but they were addressed in order to ensure that important species were identified.

Stressor characteristics chosen for the site are also a source of uncertainty. COPC from the BISRA were used. This is expected to be a highly conservative assumption, since these contaminants were chosen by performing conservative risk-based screening that used exposure parameters for humans. Offsite sources of stressors are not addressed for this assessment. Since organisms do not necessarily only inhabit the 1100 Area, they would be exposed to offsite contamination. It was not in the scope of this assessment to address these offsite exposures. It is probable that the contamination outside the 1100 Area is more significant than that identified at 1100-EM-1.

When selecting assessment endpoints, it is preferable to chose specific cases (such as reduced population size). However, with the lack of data regarding the effects of contaminants at the site on organisms known to inhabit the site, this was not possible. Therefore, adverse effects that generate the toxicological parameters (NOAEL, *etc.*) on important species (*i.e.*, the ferruginous hawk and peregrine falcon) were considered assessment endpoints. It would be preferable to use effects on these species as measurement endpoints, but data for the analog species (Swainson's hawk and long-billed curlew) were more readily available.

The simplified exposure routes introduce uncertainty that may underestimate exposure. Only ingestion of contaminated food is addressed, where other sources of contamination, such as soil ingestion, would contribute to exposure. The use of uptake factors (UF) for plants, insects, and small mammals are also a source of uncertainty. Wherever possible the most appropriate values were used. For example, when available, UF's reported for rats were used as UF's for small mammals. All parameters for the exposure calculations were taken from previously conducted studies or conservatively estimated values were used. For example, it was assumed that the Swainson's hawk and long-billed curlew consumed 100 percent of their diet from HRL and 100 percent of that diet was contaminated.

Toxicological parameters reported in table L-2 are a source of uncertainty. Only two values were derived from studies on Swainson's hawks. Values for small mammals were chosen if values for birds were not available, however, the most conservative data available are presented. For example NOAEL is used over LOAEL, and Toxic Dose Low (TDLo) is used over Lethal Dose-50 (LD50).

5.3.6 Ecological Implications

Using highly conservative assumptions and models, no uptake rates for the long-billed curlew or the Swainson's hawk exceeded toxicity values. Contaminants with uptake rates that were closest to toxicity values were zinc for the hawk and BEHP for the long-billed curlew, which were approximately 10 and 20 times less than toxicity values, respectively. Therefore, it is unlikely that contaminants of potential concern at 1100-EM-1 would have an impact on these birds that was distinguishable from background conditions. Even though there are significant uncertainties in this assessment, there has been little evidence of ecological damage at the site.

6.0 CONTAMINANT FATE AND TRANSPORT

6.1 INTRODUCTION

This chapter is organized as follows. Contaminants of concern identified in the previous chapters will be briefly discussed. Then, the description of the physical characteristics and the delineation of the extent of contamination at the 1100-EM-1 Operable Unit are combined to analyze the fate and transport of contaminants. The body of field data for the 1100-EM-1 Area has been provided in previous sections and in other reports cited. Specific models appropriate to the physical parameters identified at the site have been designated by the EPA, DOE, and Ecology to assist in predicting the movement and the fate of contaminants within the environment. A summary of the vadose zone unsaturated flow model is provided. The unsaturated flow model was used to validate assumptions used in the groundwater flow model concerning the rate of groundwater recharge from infiltration originating as atmospheric precipitation. Finally, the groundwater flow and contaminant transport model are described. Basic contaminant fate and transport principles were discussed in greater detail in the Phase I RI Report for the Hanford Site 1100-EM-1 Operable Unit (DOE/RL-90-18).

6.2 CONTAMINANTS OF CONCERN

Contaminants of concern for the 1100-EM-1 Operable Unit, as described in section 5.0, are BEHP and chlordane in the soils at the UN-1100-6, Discolored Soil Site subunit, PCB's and chlordane in the soils of the Ephemeral Pool subunit, PCB's, arsenic, beryllium, and chromium in soils of the HRL subunit, and TCE and nitrate in the groundwater of the HRL subunit. A brief discussion of each contaminant of concern will be presented in the following paragraphs.

6.2.1 Arsenic

Arsenic is a common element found in the earth's crust, usually in the form of arsenic-bearing minerals. It is difficult to characterize as a single element because of its very complex chemistry.

6.2.2 BEHP

Bis(2-ethylhexyl)phthalate (BEHP) is a compound used to render plastics more flexible. This substance and other phthalate-ester plasticizers have been found to be general contaminants in virtually all soil and water ecosystems (IRIS). BEHP is relatively immobile due to strong soil sorption, low water solubility, and low vapor pressure. Thus, migration to groundwater through the vadose zone is not expected. The high potential for bioaccumulation would be the most likely pathway of importance.

Biodegradation of BEHP under aerobic aqueous conditions has been observed to be fairly rapid, and following bacterial acclimation, a half-life of 2 to 3 weeks has been measured. Under experimental conditions, aerobic biodegradation has been observed in soil with a degradation half-life of about 14 days.

6.2.3 Beryllium

Beryllium occurs in nature in rocks, soils, and volcanic dust. It does not occur in its elemental form naturally. Beryllium compounds vary in water solubility. A major portion of beryllium will bind to soil and is not likely to migrate deeper into the ground and groundwater.

6.2.4 Chlordane

Chlordane is expected to be fairly immobile in the soil/groundwater system due to strong soil sorption and moderate volatilization. Data on degradation are limited; the contaminants are expected to be moderately persistent. Risk of groundwater contamination is moderate. Contamination of surface waters from surface runoff over chlordane-contaminated soils has been reported. Pathways of concern from the soil/groundwater system are migration into groundwater drinking supplies, uptake by crops from contaminated soils, and bioaccumulation by aquatic organisms or domestic animals.

Chlordane is not expected to undergo significant hydrolysis, oxidation, or direct photolysis. Little is known about biodegradation, but such a process would be expected to be slow. Volatilization is insignificant, but chlordane vapors in the atmosphere are known to react with photochemically produced hydroxyl radicals. The estimated half-life of these vapors is 6.2 hours.

6.2.5 Chromium

Elemental chromium does not exist naturally in the environment, but is found primarily as a constituent of chromite ore. A trivalent form of chromium is an essential human micronutrient involved in carbohydrate metabolism. Adverse effects have not been associated with the trivalent form. The hexavalent form of chromium has been associated with serious toxicities. Hexavalent chromium is mobile in soil. Under aerobic and acidic conditions, it is reduced to trivalent chromium that readily precipitates with carbonates, hydroxides, and sulfides in the soil. Hexavalent chromium does not bioaccumulate in significant amounts.

6.2.6 Nitrate

As a class, nitrate compounds are a variety of chemicals used in explosives, medications, dyes, food additives, and as numerous other industrial products. Nitrate occurs naturally, and the majority of dietary intake is from vegetables. The dietary contribution from drinking water is usually quite small. The nitrate form of nitrogen is very water soluble and is highly mobile in water and soil contributing to concern over the presence of these compounds in the environment.

6.2.7 PCB's

Polychlorinated biphenyls (PCB's) are very inert, thermally and chemically stable compounds having dielectric properties. PCB's are expected to be highly immobile in the soil/groundwater system due to rapid and strong soil sorption. In the absence of organic solvents, leaching is minimal. Being strongly sorbed to soils, migration to the groundwater is not expected. In the atmosphere, transformation takes place in a vapor-phase reaction with photochemically produced hydroxyl radicals. In general, the higher chlorinated biphenyls are less mobile and more persistent than the lower chlorinated species. The potential for PCB bioaccumulation is high.

6.2.8 TCE

Trichloroethene (TCE) is a widely used industrial solvent. It is relatively mobile in the soil/groundwater system, particularly in soils having a low organic content. Volatilization may be significant for TCE near the surface or in the soil-air phase. Biodegradation may be the most important transformation process. The biodegradation byproducts of TCE are dichloroethene and vinyl chloride. A contaminant degradation study performed on samples obtained from the 1100-EM-1 Operable Unit suggests that rapid biodegradation does not appear to occur (Golder, 1992). Transformation processes such as hydrolysis, oxidation, and photolysis are not expected to be important in natural soils. The primary pathway of concern in a soil/water system is the migration of TCE into groundwater drinking water supplies.

6.3 VADOSE ZONE MODELING

UNSAT-H™ is a one-dimensional computer code developed by Pacific Northwest Laboratory to model water flow through unsaturated media employing the finite difference numerical method (Fayer and Jones, 1990). The purpose of the model is to assess water dynamics of near-surface waste disposal sites located on the Hanford Site. It is primarily used to predict deep drainage as a function of environmental conditions such as climate, soil type, and vegetation. The model is mechanistic in that it is based on Richards' equation for liquid water flow in unsaturated media (Richards, 1931), Fick's law of diffusion for vapor flow and evaporation (Hillel, 1980), and Fourier's law of heat conduction for soil heat flow (Campbell, 1985). In the present study, the UNSAT-H™ model is used to determine groundwater recharge from surface infiltration of rainwater for the 1100-EM-1 Operable Unit. Values derived will be compared with recharge amounts input to the groundwater model to confirm their applicability.

The original UNSAT-H™ code was written for execution on a VAX™ computer system. The code was submitted to modeling specialists from the Hydraulics and Environmental Laboratories at the U.S. Army Corps of Engineers, Waterways Experiment Station in Vicksburg, Mississippi, who performed necessary modifications to allow model runs on IBM-compatible personal computers. The modified code was verified by comparing output to model output published in the UNSAT-H™ User's Manual. No significant differences in results were noted.

6.3.1 Model Input

The following paragraphs will describe the inputs used to initialize UNSAT-H model runs. Actual data will be provided where practicable and the rationale for their use will be presented.

6.3.1.1 Soil Data. Soil properties used as model input were obtained from boring logs developed during the installation of groundwater monitoring wells. Gradation curves of soil components obtained during analyses for physical properties during the Phase I RI were recomputed and reconstructed to eliminate particle sizes greater than 2.0 millimeters. Particle sizes greater than 2.0 mm (0.08 in) have minimal impact on unsaturated flow parameters (Schroeder, 1992). The curves were then compared to soil gradation curves included in Smoot *et al.*, 1989. During Smoot *et al.*'s study of vadose zone moisture flow at a location within the Hanford Site 200 Area, unsaturated flow parameters were determined from laboratory analyses of soil samples. The unsaturated flow parameters listed for soils in the 200 Area were assigned to 1100 Area soils based on the closest match of the gradation curves. Parameters assigned to the 1100 Area soils included soil conductivity at laboratory saturation, and the van Genuchten curve fitting parameters α, n, and m. Laboratory testing to determine soil unsaturated flow parameters was not performed during either the Phase I or Phase II investigations of the 1100-EM-1 Operable Unit.

Bulk density (γ) values were estimated based on classification of the 1100 Area soils and typical values tabulated in table 3.5 of Hunt, 1986. In situ bulk density measurements were not obtained during either the Phase I or Phase II investigations due to difficulties in obtaining undisturbed samples of gravelly, cobbly soils.

Specific gravities (SpG) were measured for 1100 Area soils by laboratory testing, in some instances. Where no specific gravity analysis was performed, the SpG values of similarly classified soils based on particle size gradation were assigned to the untested samples, *i.e.*, if a sandy silt had a measured SpG of 2.63, all untested sandy silts were assigned an SpG of 2.63. Where a range of SpG values were measured for similarly classified soils, the values were averaged and the average value was assigned to all untested soils having the same classification.

The in situ moisture content of the soil was measured during laboratory analysis of samples collected during the installation of Phase I monitoring wells on a weight percent (WT%) basis. Values were converted to a volumetric basis (cubic centimeters of water per cubic centimeter of soil [Θ]) using the formula:

$$\Theta = ((\gamma \times WT\%) / 0.998) / 100$$

(Jury *et al.*, 1991)

A soil residual moisture content (Θr) of zero was assigned to all vadose zone soils based on the generally coarse texture of Operable Unit soils (Fayer, 1992). Saturated moisture content (Θs) was taken to be equal to the porosity of the soil. Soil porosity was calculated based on the formula:

$$\Theta s = (1 - (\gamma / SpG))$$

(Hunt, 1986).

Soil matric potential (h) was calculated based on the van Genuchten formula:

$$h = (((((\Theta - \Theta r) / (\Theta s - \Theta r))^{(1/-m)}) - 1)^{(1/n)}) / \alpha$$

(Fayer and Jones, 1990).

Initial runs of the UNSAT-H™ model were only marginally successful. The code was experiencing computational difficulties given the very low measured soil-moisture values and the use of the van Genuchten/Mualem model option. The Brooks-Corey/Mualem model option was implemented after van Genuchten curve fitting parameters were converted to the appropriate Brooks-Corey parameters using the formulas:

$$h_e = 1 / \alpha$$

$$b = 1 / (n - 1)$$

(Fayer, 1992). The Brooks-Corey matric potential was then computed using the formula:

$$h = h_e / (\Theta / \Theta s)^b$$

(Fayer and Jones, 1990). Tables 6-1 and 6-2 present a compilation of computed parameters for the van Genuchten/Mualem and Brooks-Corey/Mualem computational models, respectively.

Computed soil parameters, laboratory measured soil properties, and soil classifications derived from field logs were compared. Monitoring well boring MW-15, located in the east-central portion of HRL was selected as being most representative of the Operable Unit vadose zone, and was used for all subsequent unsaturated flow model runs. The log was not excessively detailed so the soil column could be effectively represented by the model without resulting in extremes for computer computational time or memory usage. All UNSAT-H™ model runs were accomplished on a DELL 433DE® personal computer having a 80486 processor.

6.3.1.2 Climatic Data. Climatic data was derived from U.S. Department of Agriculture synthetic weather generating models WGEN™ and CLIGEN™ (Richardson and Wright, 1984, and U.S. Department of Agriculture). Weather data generated by these models was then compared to historic climatic records gathered at the Hanford Meteorological Station to ensure the synthetic data was reasonable. A 100-year interval was simulated using both the CLIGEN™ and WGEN™ models. Richland N.E. weather station data was used to generate weather data with CLIGEN™. The Richland N.E. station is located at the Richland Airport, approximately 1.6 km (1 mile) south of the 1100-EM-1 Operable Unit. Maximum, minimum, and dew point temperatures, average wind speed, cloud cover, and inches of precipitation were generated on a daily basis by the model. CLIGEN™ computed precipitation values were extracted from the output file and input into the WGEN™ portion of the Hydrologic Evaluation of Landfill Performance (HELP) Model (Schroeder, *et al.*, 1992) to generate solar radiation values (Langleys). WGEN™ generated solar radiation units were substituted for CLIGEN™ data because WGEN™ simulates radiation based on rainfall occurrence, a more reasonable estimation than the CLIGEN™ based values. Data values generated by both weather models were combined by use of various computer routines written to place the output into a form suitable for direct entry into the UNSAT-H™ code.

Initially, climatic data having 17.018 cm (6.700 in) of yearly precipitation was run over a simulation period of 500 years, the period of time required for steady-state base drainage (recharge) conditions to develop. Head values for model node points within the unsaturated zone were input as elevation heads in centimeters above the water table. A water table depth of 853 cm (28 ft) was used as an average for HRL vicinity. Head values, node point depths, and soil type distributions modeled are included in table 6-3. Table 6-4 presents inputs for other UNSAT-H™ model variables employed for unsaturated flow simulations. Steady-state head values for model node points were then used to initiate a 100-year simulation period with yearly data generated by the weather models used to more accurately reflect groundwater recharge within the 1100-EM-1 Operable Unit. Table 6-5 lists yearly precipitation values used for the 100-year simulation. Daily cloud cover values generated by the weather models were input to UNSAT-H™. However, an UNSAT-H™ program switch was set allowing the code to independently compute cloud cover based on input solar radiation values.

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Table 6-1: VADOSE ZONE MODELING PARAMETERS VAN GENUCHTEN MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	To	Soil Gradations LAB % G	% S	% M	Conductivity at Lab Saturation 7 (cm/s)	Residual Moisture 5 (THETA r)	Moisture Content (THETA)	Moisture Values In-Situ Moisture Weight % Measured 4	Bulk Density 1	Estimated Soil Porosity = Saturated Moisture Content 3 (THETA s)	SpG 2	van Genuchten Parameters 6 a	n	m	Calculated Suction Head 8 (cm) (h)	Wentworth Soil Classification 10
Background	BAP-2	A0202	5.5	6.5	58	33	9	[redacted]											Silty Sandy GRAVEL
		A0203	8.3	9.6	60	27	13	5.77E-04	0.00	0.0346	1.80	1.92	0.29	2.69	0.09123	1.28327	0.22074	19,923.99	Silty Sandy GRAVEL
		A0208	19.5	21.0	58	33	9	2.82E-04	0.00	0.0385	2.00	1.92	0.29	2.69	0.25119	1.60079	0.37531	114.39	Silty Sandy GRAVEL
		A0210	34.4	35.4	78	15	7	5.77E-04	0.00	0.0423	2.20	1.92	0.29	2.69	0.09123	1.28327	0.22074	9,800.96	Silty Sandy GRAVEL
	HRL-1	A0302	7.0	8.0	68	22	10	5.77E-04	0.00	0.0327	1.70	1.92	0.29	2.69	0.09123	1.28327	0.22074	24,319.71	Silty Sandy GRAVEL
		A0307	15.0	16.0	7	83	10	2.99E-04	0.00	0.0602	3.60	1.67	0.38	2.71	0.17633	1.36246	0.26603	914.21	Slightly Silty Slightly Gravelly SAND
	DP-7	A0101	0.7	2.0	54	36	10	1.38E-05	0.00	0.0462	2.40	1.92	0.29	2.69	0.15633	1.39591	0.28362	661.43	Silty Sandy GRAVEL
		A0105	16.5	18.0	70	23	7	2.82E-04	0.00	0.0308	1.60	1.92	0.29	2.69	0.25119	1.60079	0.37531	166.05	Silty Sandy GRAVEL
		A0109	28.4	30.0	25	62	13	2.82E-04	0.00	0.0593	3.70	1.60	0.41	2.73	0.25119	1.60079	0.37531	99.11	Slightly Silty Gravelly SAND
1100-1	BAP-1	A1002S	2.2	4.2	26	55	19	1.38E-05	0.00	0.1427	8.90	1.60	0.40	2.68	0.15633	1.39591	0.28362	64.78	Gravelly Silty SAND
		A1006S	6.1	6.8	54	27	19	8.88E-04	0.00	0.0904	4.70	1.92	0.29	2.69	0.54741	1.28139	0.21960	401.13	Silty Sandy GRAVEL
		A1009S	7.8	8.8	42	37	21	5.77E-04	0.00	0.0558	2.90	1.92	0.29	2.69	0.09123	1.28327	0.22074	3,685.25	Silty Sandy GRAVEL
		A1013S	13.4	13.9	44	43	13	5.77E-04	0.00	0.0616	3.20	1.92	0.29	2.69	0.09123	1.28327	0.22074	2,598.66	Silty Sandy GRAVEL
		A1015S	16.3	17.5	65	28	7	1.21E-03	0.00	0.0442	2.30	1.92	0.29	2.69	0.39456	1.34559	0.25683	585.72	Silty Sandy GRAVEL
1100-2	DP-4	A0402S	0.8	1.4	34	55	11	1.78E-04	0.00	0.0154	0.80	1.92	0.29	2.69	0.20954	1.34125	0.25443	25,976.92	Silty Sandy GRAVEL
		A0404S	1.9	3.1	31	51	18	2.99E-04	0.00	0.0616	3.20	1.92	0.29	2.69	0.17633	1.36246	0.26603	408.45	Silty Sandy GRAVEL
		A0406S	3.3	5.1	[redacted]														
		A0410S	10.7	12.4	64	28	8	1.78E-04	0.00	0.0481	2.50	1.92	0.29	2.69	0.20954	1.34125	0.25443	922.32	Silty Sandy GRAVEL
		A0412S	16.0	17.0	60	32	8	1.38E-05	0.00	0.0519	2.70	1.92	0.29	2.69	0.15633	1.39591	0.28362	492.74	Silty Sandy GRAVEL
	DP-5	A0503S	2.6	3.6	48	39	13	8.88E-04	0.00	0.0558	2.90	1.92	0.29	2.69	0.54741	1.28139	0.21960	2,235.70	Silty Sandy GRAVEL
		A0505S	6.6	7.1	35	48	17	2.24E-04	0.00	0.1039	5.40	1.92	0.29	2.69	0.48677	1.29968	0.23058	62.56	Silty Sandy GRAVEL
		A0509S	10.0	11.0	48	45	7	5.73E-04	0.00	0.0846	4.40	1.92	0.29	2.69	0.08632	1.31349	0.23867	587.04	Silty Sandy GRAVEL
		A0512S	15.0	15.7	33	60	7	1.21E-03	0.00	0.0923	4.80	1.92	0.29	2.69	0.39456	1.34559	0.25683	69.00	Silty Sandy GRAVEL
		A0513S	16.2	18.0	4	93	3	2.99E-04	0.00	0.0703	4.20	1.67	0.37	2.65	0.17633	1.36246	0.26603	553.28	SAND
	DP-6	A0603S	0.5	2.0	42	45	13	5.77E-04	0.00	0.0231	1.20	1.92	0.29	2.69	0.09123	1.28327	0.22074	82,948.31	Silty Sandy GRAVEL
		A0604S	2.5	3.7	36	42	22	5.77E-04	0.00	0.0308	1.60	1.92	0.29	2.69	0.09123	1.28327	0.22074	30,042.61	Silty Sandy GRAVEL
		A0607S	4.2	5.7	39	41	20	1.38E-05	0.00	0.0827	4.30	1.92	0.29	2.69	0.15633	1.39591	0.28362	150.84	Silty Sandy GRAVEL
		A0609S	7.9	9.0	54	38	8	1.21E-03	0.00	0.0442	2.30	1.92	0.29	2.69	0.39456	1.34559	0.25683	585.72	Silty Sandy GRAVEL
		A0611S	12.8	13.8	32	61	7	1.21E-03	0.00	0.0616	3.20	1.92	0.29	2.69	0.39456	1.34559	0.25683	223.87	Silty Sandy GRAVEL
		A0614S	16.3	17.3	14	79	7	5.73E-04	0.00	0.0535	3.20	1.67	0.37	2.66	0.08632	1.31349	0.23867	5,531.07	Gravelly SAND
	DP-9	A1102S	2.6	3.6	43	40	17	1.38E-05	0.00	0.0500	2.60	1.92	0.29	2.69	0.15633	1.39591	0.28362	541.53	Silty Sandy GRAVEL
		A1104S	6.75	7.1	51	34	15	5.77E-04	0.00	0.1154	7.20	1.60	0.41	2.69	0.09123	1.28327	0.22074	960.36	Silty Sandy GRAVEL
		A1108S	9.0	9.2	23	69	8	1.21E-03	0.00	0.0731	3.80	1.92	0.30	2.73	0.39456	1.34559	0.25683	150.29	Slightly Silty Gravelly SAND
		A1109S	9.2	11.5	25	70	5	2.99E-04	0.00	0.0653	3.90	1.67	0.37	2.66	0.17633	1.36246	0.26603	678.42	Gravelly SAND
		A1110S	9.2	11.5	21	72	7	2.99E-04	0.00	0.1807	10.80	1.67	0.37	2.66	0.17633	1.36246	0.26603	33.91	Gravelly SAND
		A1112S	13.5	14.5	18	76	6	2.99E-04	0.00	0.0885	4.60	1.92	0.28	2.66	0.17633	1.36246	0.26603	134.76	Gravelly SAND
		A1113S	15.5	16.5	26	66	8	5.73E-04	0.00	0.0641	4.00	1.60	0.41	2.73	0.08632	1.31349	0.23867	4,310.85	Slightly Silty Gravelly SAND
		A1117S	21.8	22.1	45	49	6	2.82E-04	0.00	0.0577	3.00	1.92	0.29	2.69	0.25119	1.60079	0.37531	58.00	Silty Sandy GRAVEL
		A1120S	25.0	26.0	69	24	7	1.21E-03	0.00	0.0519	2.70	1.92	0.29	2.69	0.39456	1.34559	0.25683	367.87	Silty Sandy GRAVEL
		A1122S	31.1	32.1	62	28	10	2.82E-04	0.00	0.0481	2.50	1.92	0.29	2.69	0.25119	1.60079	0.37531	78.78	Silty Sandy GRAVEL
		A1124S	35.5	36.8	60	29	11	5.77E-04	0.00	0.0712	3.70	1.92	0.29	2.69	0.09123	1.28327	0.22074	643.69	Silty Sandy GRAVEL
1100-3	DP-1	A0902S	4.0	5.1	48	42	12	1.21E-03	0.00	0.0481	2.50	1.92	0.29	2.69	0.39456	1.34559	0.25683	458.51	Silty Sandy GRAVEL
		A0905S	6.9	7.9	48	42	10	1.78E-04	0.00	0.0462	2.40	1.92	0.29	2.69	0.20954	1.34125	0.25443	1,038.04	Silty Sandy GRAVEL
		A0908S	11.9	12.9	15	73	12	1.38E-05	0.00	0.0830	4.90	1.69	0.38	2.73	0.15633	1.39591	0.28362	297.39	Slightly Silty Gravelly SAND
		A0911S	15.5	16.5	2	91	7	5.73E-04	0.00	0.0971	5.80	1.67	0.37	2.65	0.08632	1.31349	0.23867	824.02	SAND
	DP-2	A0802S	2.0	3.5	39	51	10	1.21E-03	0.00	0.0250	1.30	1.92	0.29	2.69	0.39456	1.34559	0.25683	3,047.90	Silty Sandy GRAVEL
		A0804S	6.5	8.0	54	36	10	2.82E-04	0.00	0.0519	2.70	1.92	0.29	2.69	0.25119	1.60079	0.37531	69.34	Silty Sandy GRAVEL
		A0806S	8.5	10.2	9	86	5	1.78E-04	0.00	0.0647	3.80	1.70	0.37	2.71	0.20954	1.34125	0.25443	789.86	Slightly Gravelly SAND
		A0807S	12.6	14.3	10	82	8	5.73E-04	0.00	0.0664	3.90	1.70	0.37	2.71	0.08632	1.31349	0.23867	2,775.90	Slightly Gravelly SAND
	DP-2	A0809S	15.0	16.0	40	47	13	2.82E-04	0.00	0.0539	2.80	1.92	0.29	2.69	0.25119	1.60079	0.37531	65.06	Silty Sandy GRAVEL
		A0811S	17.6	20.0	14	79	7	1.21E-03	0.00	0.0602	3.60	1.67	0.37	2.66	0.39456	1.34559	0.25683	484.77	Gravelly SAND
	DP-3	A0703S	2.3	3.3	41	40	19	8.88E-04	0.00	0.0289	1.50	1.92	0.29	2.69	0.08632	1.31349	0.23867	18,135.96	Silty Sandy GRAVEL
		A0705S	7.1	8.1	60	35	5	3.64E-03	0.00	0.0481	2.50	1.92	0.29	2.69	0.10074	1.40147	0.28646	870.41	Silty Sandy GRAVEL
		A0707S	10.1	10.8	14	81	5	2.99E-04	0.00	0.0736	4.40	1.67	0.37	2.66	0.17633	1.36246	0.26603	487.37	Gravelly SAND
		A0710S	13.2	14.3	3	94	3	2.99E-04	0.00	0.0619	3.70	1.67	0.37	2.65	0.17633	1.36246	0.26603	786.42	SAND

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Table 6-1: VADOSE ZONE MODELING PARAMETERS VAN GENUCHTEN MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Conductivity at Lab Saturation 7 (cm/s)	Residual Moisture 5 (THETA r)	Moisture Content (THETA)	Moisture Values In-Situ Moisture Weight % Measured 4	Bulk Density 1	Estimated Soil Porosity = Saturated Moisture Content 3 (THETA s)	SpG 2	van Genuchten Parameters 6 a	n	m	Calculated Suction Head 8 (cm) (h)	Wentworth Soil Classification 10
		A0811S	17.6	20.0	14	79	7	1.21E-03	0.00	0.0602	3.60	1.67	0.37	2.66	0.39456	1.34559	0.25683	484.77	Gravelly SAND
	DP-3	A0703S	2.3	3.3	41	40	19	8.88E-04	0.00	0.0289	1.50	1.92	0.29	2.69	0.08632	1.31349	0.23867	18,135.96	Silty Sandy GRAVEL
		A0705S	7.1	8.1	60	35	5	3.64E-03	0.00	0.0481	2.50	1.92	0.29	2.69	0.10074	1.40147	0.28646	870.41	Silty Sandy GRAVEL
		A0707S	10.1	10.8	14	81	5	2.99E-04	0.00	0.0736	4.40	1.67	0.37	2.66	0.17633	1.36246	0.26603	487.37	Gravelly SAND
		A0710S	13.2	14.3	3	94	3	2.99E-04	0.00	0.0619	3.70	1.67	0.37	2.65	0.17633	1.36246	0.26603	786.42	SAND
		A0711S	15.2	16.0	5	93	2	2.99E-04	0.00	0.0645	3.90	1.65	0.39	2.71	0.17633	1.36246	0.26603	811.80	Slightly Gravelly SAND
	DP-8	A1202S	2.5	3.7	41	47	12	3.64E-03	0.00	0.0289	1.50	1.92	0.29	2.69	0.10074	1.40147	0.28646	3,099.65	Silty Sandy GRAVEL
		A1207S	7.7	8.9	42	49	9	5.73E-04	0.00	0.0404	2.10	1.92	0.29	2.69	0.08632	1.31349	0.23867	6,228.73	Silty Sandy GRAVEL
		A1212S	15.1	16.1	54	40	6	2.82E-04	0.00	0.0385	2.00	1.92	0.29	2.69	0.25119	1.60079	0.37531	114.39	Silty Sandy GRAVEL
		A1214S	18.3	18.7	34	56	10	2.82E-04	0.00	0.0404	2.10	1.92	0.29	2.69	0.25119	1.60079	0.37531	105.53	Silty Sandy GRAVEL
		A1215S	20.5	22.2	17	73	10	1.21E-03	0.00	0.0423	2.50	1.69	0.38	2.73	0.39456	1.34559	0.25683	1,454.54	Slightly Silty Gravelly SAND
		A1216S	23.7	26.4	19	73	8	1.21E-03	0.00	0.0502	3.00	1.67	0.37	2.66	0.39456	1.34559	0.25683	820.28	Gravelly SAND
		A1218S	26.4	27.4	54	33	13	5.77E-04	0.00	0.0385	2.00	1.92	0.29	2.69	0.09123	1.28327	0.22074	5,647.53	Silty Sandy GRAVEL
		A1220S	30.2	31.4	54	39	7	2.82E-04	0.00	0.0442	2.30	1.92	0.29	2.69	0.25119	1.60079	0.37531	90.79	Silty Sandy GRAVEL
HRL	HRL-2	A1803S	3.4	4.8	51	35	14	5.77E-04	0.00	0.0596	3.10	1.92	0.29	2.69	0.09123	1.28327	0.22074	1,206.84	Silty Sandy GRAVEL
		A1806S	8.0	8.9	36	54	10	2.82E-04	0.00	0.0346	1.80	1.92	0.29	2.69	0.25119	1.60079	0.37531	136.74	Silty Sandy GRAVEL
		A1809S	12.5	13.5	54	34	12	5.77E-04	0.00	0.0327	1.70	1.92	0.29	2.69	0.09123	1.28327	0.22074	10,051.31	Silty Sandy GRAVEL
		A1811S	16.5	17.6	58	29	13	5.77E-04	0.00	0.0327	1.70	1.92	0.29	2.69	0.09123	1.28327	0.22074	10,051.31	Silty Sandy GRAVEL
		A1813S	20.0	21.7	48	35	17	5.77E-04	0.00	0.0442	2.30	1.92	0.29	2.69	0.09123	1.28327	0.22074	3,468.57	Silty Sandy GRAVEL
	HRL-3	A2003S	2.8	4.4	54	34	12	2.82E-04	0.00	0.0544	2.83	1.92	0.29	2.69	0.25119	1.60079	0.37531	64.06	Silty Sandy GRAVEL
		A2006S	8.0	9.3	68	24	8	5.77E-04	0.00	0.0577	3.00	1.92	0.29	2.69	0.09123	1.28327	0.22074	1,353.19	Silty Sandy GRAVEL
		A2008S	13.3	14.5	47	45	8	2.82E-04	0.00	0.1083	5.63	1.92	0.29	2.69	0.25119	1.60079	0.37531	19.57	Silty Sandy GRAVEL
		A2011S	17.6	18.8	61	29	10	5.77E-04	0.00	0.0558	2.90	1.92	0.29	2.69	0.09123	1.28327	0.22074	1,523.08	Silty Sandy GRAVEL
		A2013S	22.0	23.2	68	25	7	5.77E-04	0.00	0.0687	3.57	1.92	0.29	2.69	0.09123	1.28327	0.22074	730.40	Silty Sandy GRAVEL
	HRL-4	A2203S	3.2	4.6	56	34	10	3.64E-03	0.00	0.0654	3.40	1.92	0.29	2.69	0.10074	1.40147	0.28646	403.86	Silty Sandy GRAVEL
		A2206S	8.2	9.7	66	24	10	5.77E-04	0.00	0.0462	2.40	1.92	0.29	2.69	0.09123	1.28327	0.22074	2,966.78	Silty Sandy GRAVEL
		A2209S	13.6	14.4	37	48	15	2.82E-04	0.00	0.0616	3.20	1.92	0.29	2.69	0.25119	1.60079	0.37531	51.94	Silty Sandy GRAVEL
		A2211S	17.4	18.9	59	28	13	5.77E-04	0.00	0.0414	2.15	1.92	0.29	2.69	0.09123	1.28327	0.22074	4,370.21	Silty Sandy GRAVEL
		A2213S	21.5	23.5	71	22	7	5.77E-04	0.00	0.0604	3.14	1.92	0.29	2.69	0.09123	1.28327	0.22074	1,151.31	Silty Sandy GRAVEL
	HRL-5	A1503S	3.8	6.0	60	35	5	1.78E-04	0.00	0.1347	7.00	1.92	0.29	2.69	0.20954	1.34125	0.25443	43.48	Silty Sandy GRAVEL
		A1505S	8.6	9.4	53	37	10	3.64E-03	0.00	0.0712	3.70	1.92	0.29	2.69	0.10074	1.40147	0.28646	326.38	Silty Sandy GRAVEL
		A1508S	11.8	13.1	59	28	13	5.77E-04	0.00	0.0414	2.15	1.92	0.29	2.69	0.09123	1.28327	0.22074	4,370.21	Silty Sandy GRAVEL
		A1511S	15.5	16.0	51	30	19	5.77E-04	0.00	0.0304	1.58	1.92	0.29	2.69	0.09123	1.28327	0.22074	13,002.79	Silty Sandy GRAVEL
		A1514S	21.9	22.8	48	32	20	5.77E-04	0.00	0.0308	1.60	1.92	0.29	2.69	0.09123	1.28327	0.22074	12,416.36	Silty Sandy GRAVEL
	HRL-6	A1604S	7.1	9.4	65	33	2	1.78E-04	0.00	0.3174	16.50	1.92	0.29	2.70	0.20954	1.34125	0.25443	(-1.35,1.39)	Sandy GRAVEL
		A1606S	9.4	11.6	75	21	4	2.82E-04	0.00	0.1010	5.25	1.92	0.29	2.69	0.25119	1.60079	0.37531	22.16	Silty Sandy GRAVEL
		A1609S	16.2	18.5	80	18	2	2.82E-04	0.00	0.1731	9.00	1.92	0.29	2.70	0.25119	1.60079	0.37531	7.83	Sandy GRAVEL
		A1610S	18.5	20.8	80	18	2	2.82E-04	0.00	0.1731	9.00	1.92	0.29	2.70	0.25119	1.60079	0.37531	7.83	Sandy GRAVEL
		A1611S	21.5	23.0	51	35	14	5.77E-04	0.00	0.0481	2.50	1.92	0.29	2.69	0.09123	1.28327	0.22074	2,573.23	Silty Sandy GRAVEL
		A1614S	24.2	25.0	32	41	27	5.77E-04	0.00	0.0292	1.52	1.92	0.29	2.69	0.09123	1.28327	0.22074	14,989.41	Silty Sandy GRAVEL
		A1615S	25.0	25.2	36	38	26	8.88E-04	0.00	0.0281	1.46	1.92	0.29	2.69	0.05474	1.28139	0.21960	73,128.95	Silty Sandy GRAVEL
		A1616S	25.8	27.8	74	20	6	5.77E-04	0.00	0.0641	3.33	1.92	0.29	2.69	0.09123	1.28327	0.22074	933.15	Silty Sandy GRAVEL
	HRL-7	A2302S	2.7	4.3	70	23	7	3.64E-03	0.00	0.0633	3.29	1.92	0.29	2.69	0.10074	1.40147	0.28646	438.25	Silty Sandy GRAVEL
		A2305S	7.3	8.4	58	30	12	5.77E-04	0.00	0.0481	2.50	1.92	0.29	2.69	0.09123	1.28327	0.22074	2,573.23	Silty Sandy GRAVEL
		A2309S	11.2	12.2	58	30	12	3.64E-03	0.00	0.0481	2.50	1.92	0.29	2.69	0.10074	1.40147	0.28646	870.41	Silty Sandy GRAVEL
		A2311S	15.3	16.5	64	23	13	5.77E-04	0.00	0.0341	1.77	1.92	0.29	2.69	0.09123	1.28327	0.22074	8,668.39	Silty Sandy GRAVEL
		A2313S	19.0	20.0	56	29	15	5.77E-04	0.00	0.0371	1.93	1.92	0.29	2.69	0.09123	1.28327	0.22074	6,436.56	Silty Sandy GRAVEL
	HRL-8	A1403S	2.5	4.4	79	16	5	5.77E-04	0.00	0.0616	3.20	1.92	0.29	2.69	0.09123	1.28327	0.22074	1,074.00	Silty Sandy GRAVEL
		A1405S	7.5	8.2	24	54	22	1.38E-05	0.00	0.0471	2.45	1.92	0.28	2.68	0.15633	1.39591	0.28362	576.40	Gravelly Silty SAND
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.40	1.92	0.29	2.69	0.54741	1.28139	0.21960	29,902.75	Silty Sandy GRAVEL

Table 6-1: VADOSE ZONE MODELING PARAMETERS
VAN GENUCHTEN MODEL

9 3 1 2 9 3 3 0 2 9 8

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Conductivity at Lab Saturation 7 (cm/s)	Residual Moisture 5 (THETA r)	Moisture Content (THETA)	Moisture Values In-Situ Moisture Weight % Measured 4	Bulk Density 1	Estimated Soil Porosity = Saturated Moisture Content 3 (THETA s)	SpG 2	van Genuchten Parameters 6 a	n	m	Calculated Suction Head 8 (cm) (h)	Wentworth Soil Classification 10
		A1413S	22.6	23.1	48	29	23	5.77E-04	0.00	0.0242	1.26	1.92	0.29	2.69	0.09123	1.28327	0.22074	29,089.82	Silty Sandy GRAVEL
HRL	HRL-9	A1703S	2.8	3.7	58	32	10	2.82E-04	0.00	0.0616	3.20	1.92	0.29	2.69	0.25119	1.60079	0.37531	51.94	Silty Sandy GRAVEL
		A1705S	5.0	5.8	51	31	18	5.77E-04	0.00	0.0331	1.72	1.92	0.29	2.69	0.09123	1.28327	0.22074	9,628.84	Silty Sandy GRAVEL
		A1708S	9.4	10.4	65	25	10	5.77E-04	0.00	0.0481	2.50	1.92	0.29	2.69	0.09123	1.28327	0.22074	2,573.23	Silty Sandy GRAVEL
		A1711S	14.2	15.2	69	21	10	5.77E-04	0.00	0.0404	2.10	1.92	0.29	2.69	0.09123	1.28327	0.22074	4,764.26	Silty Sandy GRAVEL
		A1713S	20.4	21.7	74	19	7	2.82E-04	0.00	0.0521	2.71	1.92	0.29	2.69	0.25119	1.60079	0.37531	68.89	Silty Sandy GRAVEL
	HRL-10	A1907S	9.1	11.4	73	21	6	2.82E-04	0.00	0.0481	2.50	1.92	0.29	2.69	0.25119	1.60079	0.37531	78.78	Silty Sandy GRAVEL
		A1908S	11.4	13.7	54	37	9	2.82E-04	0.00	0.0423	2.20	1.92	0.29	2.69	0.25119	1.60079	0.37531	97.72	Silty Sandy GRAVEL
		A1910S	16.9	17.8	32	51	17	5.77E-04	0.00	0.0712	3.70	1.92	0.29	2.69	0.09123	1.28327	0.22074	643.69	Silty Sandy GRAVEL
		A1911S	17.8	20.1	63	30	7	2.82E-04	0.00	0.0577	3.00	1.92	0.29	2.69	0.25119	1.60079	0.37531	58.00	Silty Sandy GRAVEL
		A1913S	27.9	30.3	81	17	2	3.64E-03	0.00	0.0693	3.60	1.92	0.29	2.69	0.10074	1.40147	0.28646	349.29	Silty Sandy GRAVEL
Monitoring Wells	MW-1	1	10.5	12.1	73	22	5	5.77E-04	0.00	0.0242	1.26	1.92	0.29	2.69	0.09123	1.28327	0.22074	29,089.82	Silty Sandy GRAVEL
		2	21.0	22.0	63	33	4	2.28E-04	0.00	0.0731	3.80	1.92	0.29	2.69	0.25119	1.60079	0.37531	36.83	Silty Sandy GRAVEL
		3	29.3	31.3	60	35	5	2.28E-04	0.00	0.0525	2.73	1.92	0.29	2.69	0.25119	1.60079	0.37531	68.01	Silty Sandy GRAVEL
		4	34.0	35.0	86	13	1	1.78E-04	0.00	0.0346	1.77	1.95	0.28	2.72	0.20954	1.34125	0.25443	2,186.04	GRAVEL
		5	40.0	41.7	32	64	4	5.73E-04	0.00	0.0806	4.19	1.92	0.29	2.70	0.08632	1.31349	0.23867	685.67	Sandy GRAVEL
	MW-2	1	11.5	12.8	58	36	6	1.21E-03	0.00	0.0419	2.18	1.92	0.29	2.69	0.39456	1.34559	0.25683	683.73	Silty Sandy GRAVEL
		2	19.0	20.0	60	33	7	1.21E-03	0.00	0.0339	1.76	1.92	0.29	2.69	0.39456	1.34559	0.25683	1,262.52	Silty Sandy GRAVEL
	MW-3	A2403	2.5	4.1	14	63	23	8.88E-04	0.00	0.0871	5.43	1.60	0.40	2.65	0.54741	1.28139	0.21960	1,439.99	Gravelly Silty SAND
		A2406	7.4	8.8	65	27	8	1.38E-05	0.00	0.0498	2.59	1.92	0.28	2.65	0.15633	1.39591	0.28362	500.55	Silty Sandy GRAVEL
		A2408	15.1	16.9	77	18	5	2.82E-04	0.00	0.0477	2.48	1.92	0.28	2.65	0.25119	1.60079	0.37531	76.32	Silty Sandy GRAVEL
		A2410	23.2	24.8	45	45	10	5.73E-04	0.00	0.0523	2.72	1.92	0.28	2.65	0.08632	1.31349	0.23867	2,443.02	Silty Sandy GRAVEL
		A2412	35.3	37.0	68	24	8	2.82E-04	0.00	0.0687	3.57	1.92	0.28	2.65	0.25119	1.60079	0.37531	40.66	Silty Sandy GRAVEL
		A2414	36.6	39.2	60	23	17	5.77E-04	0.00	0.0810	4.21	1.92	0.28	2.65	0.09123	1.28327	0.22074	360.18	Silty Sandy GRAVEL
	MW-4	1	8.5	9.5	48	46	6	1.21E-03	0.00	0.0385	2.00	1.92	0.29	2.69	0.39456	1.34456	0.25626	873.55	Silty Sandy GRAVEL
		2	16.0	17.0	40	55	5	2.82E-04	0.00	0.0577	3.00	1.92	0.29	2.70	0.25119	1.60079	0.37531	58.00	Sandy GRAVEL
		3	31.0	32.0	65	32	3	1.21E-03	0.00	0.0416	2.16	1.92	0.29	2.70	0.39456	1.34559	0.25683	698.11	Sandy GRAVEL
	MW-5	1	2.4	2.5	2	94	4	5.73E-04	0.00	0.0403	2.41	1.67	0.37	2.65	0.08632	1.31349	0.23867	13,658.10	SAND
		2	5.8	6.0	54	41	5	2.99E-04	0.00	0.0464	2.41	1.92	0.29	2.69	0.17633	1.36246	0.26603	889.51	Silty Sandy GRAVEL
		4	18.5	19.0	39	57	4	2.82E-04	0.00	0.0406	2.11	1.92	0.29	2.70	0.25119	1.60079	0.37531	104.66	Sandy GRAVEL
		5	34.5	35.0	75	22	3	2.82E-04	0.00	0.0283	1.47	1.92	0.29	2.69	0.25119	1.60079	0.37531	191.24	Silty Sandy GRAVEL
		6	48.0	48.5	72	22	6	5.77E-04	0.00	0.0877	4.56	1.92	0.29	2.69	0.09123	1.28327	0.22074	307.75	Silty Sandy GRAVEL
	MW-6	1	24.0	25.0	55	33	12	5.77E-04	0.00	0.0400	2.08	1.92	0.32	2.81	0.09123	1.28327	0.22074	6,985.41	Silty Sandy GRAVEL
		2	43.0	44.4	80	19	1	5.73E-04	0.00	0.0800	4.16	1.92	0.29	2.70	0.08632	1.31349	0.23867	702.29	Sandy GRAVEL
	MW-8	1	3.5	4.0	58	37	5	2.82E-04	0.00	0.0352	1.83	1.92	0.29	2.69	0.25119	1.60079	0.37531	132.87	Silty Sandy GRAVEL
	MW-9	1	4.6	5.2	51	36	13	5.77E-04	0.00	0.0587	3.05	1.92	0.29	2.69	0.09123	1.28327	0.22074	1,803.05	Silty Sandy GRAVEL
		2			59	33	8	2.41E-05	0.00	0.0317	1.65	1.92	0.29	2.69	0.15208	1.22993	0.18695	99,731.66	Silty Sandy GRAVEL
		3	14.1	15.2	23	73	4	2.99E-04	0.00	0.0474	2.83	1.67	0.37	2.66	0.17633	1.36246	0.26603	1,943.22	Gravelly SAND
	MW-10	1	9.5	10.5	22	73	5	2.99E-04	0.00	0.0413	2.47	1.67	0.37	2.66	0.17633	1.36246	0.26603	2,403.34	Gravelly SAND
		2	14.5	15.0	65	26	9	5.77E-04	0.00	0.0358	1.86	1.92	0.29	2.69	0.09123	1.28327	0.22074	10,334.21	Silty Sandy GRAVEL
		3	18.6	19.0	68	26	6	1.78E-04	0.00	0.0435	2.26	1.92	0.29	2.69	0.20954	1.34125	0.25443	1,238.51	Silty Sandy GRAVEL
	MW-11	1	8.6	9.4	51	46	3	2.99E-04	0.00	0.0314	1.63	1.92	0.29	2.70	0.17633	1.36246	0.26603	2,613.90	Sandy GRAVEL
	MW-12	1	1.0	1.5	0	98	2	5.77E-04	0.00	0.0686	4.10	1.67	0.37	2.65	0.08632	1.31349	0.23867	2,501.57	SAND
		2	3.5	4.0	9	68	23	8.88E-04	0.00	0.1068	6.66	1.60	0.41	2.70	0.54741	1.28139	0.21960	760.95	Slightly Gravelly Silty SAND
	MW-12	3	5.5	6.0	9	82	9	1.80E-03	0.00	0.0336	2.03	1.65	0.39	2.71	0.07607	1.38880	0.27995	7,198.91	Slightly Gravelly SAND
		4	6.5	7.0	52	42	6	1.80E-03	0.00	0.0371	1.93	1.92	0.29	2.69	0.07607	1.38880	0.27995	2,603.09	Silty Sandy GRAVEL
		5	7.0	7.5	26	71	3	2.41E-05	0.00	0.0348	2.08	1.67	0.38	2.70	0.15208	1.22993	0.18695	*********	Gravelly SAND

Table 6-1: VADOSE ZONE MODELING PARAMETERS
VAN GENUCHTEN MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Conductivity at Lab Saturation [7] (cm/s)	Residual Moisture [5] (THETA r)	Moisture Content (THETA)	Moisture Values In-Situ Moisture Weight % Measured [4]	Bulk Density [1]	Estimated Soil Porosity = Saturated Moisture Content [3] (THETA s)	SpG [2]	van Genuchten Parameters [6] a	n	m	Calculated Suction Head [8] (cm) (h)	Wentworth Soil Classification [10]
		6	10.0	10.5	61	33	6	2.82E-04	0.00	0.0552	2.87	1.92	0.29	2.69	0.25119	1.60079	0.37531	62.50	Silty Sandy GRAVEL
		7	11.5	12.0	46	50	4	1.78E-04	0.00	0.0487	2.53	1.92	0.29	2.70	0.20954	1.34125	0.25443	889.39	Sandy GRAVEL
		8	16.5	17.0	66	27	7	1.38E-05	0.00	0.0660	3.43	1.92	0.29	2.69	0.15633	1.39591	0.28362	267.93	Silty Sandy GRAVEL
		9	26.5	27.0	72	23	5	1.80E-03	0.00	0.0527	2.74	1.92	0.29	2.69	0.07607	1.38880	0.27995	1,054.16	Silty Sandy GRAVEL
		10	33.5	34.0	73	22	5	1.38E-05	0.00	0.0868	4.51	1.92	0.29	2.69	0.15633	1.39591	0.28362	133.27	Silty Sandy GRAVEL
Monitoring Wells	MW-13	1	9.5	10.0	62	35	3	1.78E-04	0.00	0.0535	2.78	1.92	0.29	2.70	0.20954	1.34125	0.25443	675.04	Sandy GRAVEL
		2	13.0	13.5	47	51	2	5.73E-04	0.00	0.0448	2.33	1.92	0.29	2.70	0.08632	1.31349	0.23867	4,478.56	Sandy GRAVEL
		3	14.0	14.5	63	30	7	2.82E-04	0.00	0.0446	2.32	1.92	0.29	2.69	0.25119	1.60079	0.37531	89.43	Silty Sandy GRAVEL
		4	17.5	18.0	86	12	2	2.82E-04	0.00	0.0574	2.94	1.95	0.28	2.72	0.25119	1.60079	0.37531	55.15	GRAVEL
		5	25.5	26.0	77	19	4	1.38E-05	0.00	0.0210	1.09	1.92	0.29	2.69	0.15633	1.39591	0.28362	4,851.06	Silty Sandy GRAVEL
	MW-14	1	7.6	8.8	53	39	8	1.38E-05	0.00	0.0866	4.50	1.92	0.29	2.69	0.15633	1.39591	0.28362	134.06	Silty Sandy GRAVEL
		2	10.8	11.5	50	44	6	2.82E-04	0.00	0.0535	2.78	1.92	0.29	2.69	0.25119	1.60079	0.37531	62.10	Silty Sandy GRAVEL
		3	20.5	21.0	82	16	2	2.82E-04	0.00	0.0467	2.39	1.95	0.28	2.72	0.25119	1.60079	0.37531	78.05	GRAVEL
		4	21.5	22.0	58	31	11	1.38E-05	0.00	0.0265	1.38	1.92	0.29	2.69	0.15633	1.39591	0.28362	2,695.39	Silty Sandy GRAVEL
	MW-15	1	5.0	7.0	54	38	8	1.78E-04	0.00	0.0350	1.82	1.92	0.29	2.69	0.20954	1.34125	0.25443	2,342.59	Silty Sandy GRAVEL
		2	9.0	10.0	55	40	5	2.82E-04	0.00	0.0402	2.09	1.92	0.29	2.69	0.25119	1.60079	0.37531	106.41	Silty Sandy GRAVEL
		3	14.5	15.0	73	22	5	1.80E-03	0.00	0.0454	2.36	1.92	0.29	2.69	0.07607	1.38880	0.27995	1,547.94	Silty Sandy GRAVEL
		4	19.5	20.0	72	24	4	1.80E-03	0.00	0.0352	1.83	1.92	0.29	2.69	0.07607	1.38880	0.27995	2,980.21	Silty Sandy GRAVEL
		5	24.7	25.2	68	22	10	5.77E-04	0.00	0.0256	1.33	1.92	0.28	2.67	0.09123	1.28327	0.22074	21,072.42	Silty Sandy GRAVEL
	MW-17	2	15.0	16.0	72	23	5	2.82E-04	0.00	0.0335	1.74	1.92	0.29	2.69	0.25119	1.60079	0.37531	144.32	Silty Sandy GRAVEL
		5	30.0	31.0	0	88	12	2.41E-05	0.00	0.1341	6.97	1.92	0.30	2.74	0.15208	1.22993	0.18695	215.76	Slightly Silty SAND
		6	35.0	36.0	28	65	7	2.82E-04	0.00	0.0512	3.06	1.67	0.37	2.66	0.25119	1.60079	0.37531	106.72	Gravelly SAND
		7	37.0	38.0	52	41	7	2.82E-04	0.00	0.1401	7.28	1.92	0.26	2.59	0.25119	1.60079	0.37531	9.75	Silty Sandy GRAVEL
Sum					****	****	****	1.07E-01	0.00	9.89	534.54	319.13	51.32	457.12	32.43114	*********	46.88822	*********	
n					168	168	168	168	168	168	168	168	168	168	168	168	168	168	
Average					50	42	9	6.38E-04	0.00	0.06	3.18	1.90	0.31	2.72	0.19304	1.40728	0.27910	5,860.62	

NOTES:

1. Bulk density values estimated from table 3.5, Geotechnical Engineering Analysis and Design, R.E. Hunt.
2. Specific gravity values from lab testing were used for all similarly classified soils; the average of measured Silty Sandy Gravel specific gravity analyses were used in the similar soil type where no testing was performed; all other values were estimated.
3. Soil porosity calculated from (1-(bulk density/specific gravity)). Soil porosity is assumed equal to the saturated moisture content.
4. Soil in-situ moisture calculated from (((bulk density * weight % measured)/0.998)/100). Units in cubic cm./cubic cm. 0.998 = grams water per cubic cm.
5. Soil residual moisture value of zero was the recommended value for sands and gravels per Mr. Michael Fayer, PNL.
6. Van Genuchten parameters derived from first converting lab gradations to exclude partical sizes >2mm diameter. Second, the converted gradation curves were visually compared to curves for soils listed in the document, Simulations of Infiltration of Meteoric Water and Contaminan Movement in the Vadose Zone at Single-Shell Tank 241-T-106 at the Hanford Site", WHC-EP-0332. Finally, values listed in the publication for the van Genuchten parameters were assigned to 1100-EM-1 soils having the closest gradation curve match.
7. Soil Conductivity at Lab Saturation was obtained in the same method as the van Genuchten parameters (see note 6).
8. Calculated suction head was obtained using an HP28S calculator and the formula:
   (((((in-situ moisture - residual moisture)/(saturated moisture - residual moisture))^(1/-m)) - 1)^(1/n))/a.
   Suction head is the absolute value of soil matric potential.
9. Shaded rows indicate questionably high in-situ moisture values. Not intended for use.
10. Wentworth Soil Classification entries based on laboratory particle size gradations, NOT on field log gradations.

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Table 6-2: VADOSE ZONE MODELING PARAMETERS BROOKS-COREY MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Soil Conductivity at Lab Saturation [7] Ks(cm/s)	In-Situ Soil Conduct. Kl(cm/sec)	Residual Moisture [5] (THETA r)	Moisture Values In-Situ Moisture Content (THETA)	Moisture Weight % Measured [4]	Bulk Density [1]	Estimated Soil Porosity = Saturated Moisture Content [3] (THETA s)	SpG[2]	Brooks-Corey Parameters [6] he	b	b'	Calculated Suction Head [8] (cm) (h)
Background	BAP-2	A0202	5.5	6.5	58	33	9	[redacted]											
		A0203	8.3	9.6	60	27	13	5.77E-04	3.41E-13	0.00	0.0346	1.80	1.92	0.29	2.69	10.96131	3.53020	3.00000	18,971.38
		A0208	19.5	21.0	58	33	9	2.82E-04	8.60E-10	0.00	0.0385	2.00	1.92	0.29	2.69	3.98105	1.66448	3.00000	112.37
		A0210	34.4	35.4	78	15	7	5.77E-04	2.57E-12	0.00	0.0423	2.20	1.92	0.29	2.69	10.96131	3.53020	3.00000	9,342.03
	HRL-1	A0302	7.0	8.0	68	22	10	5.77E-04	1.92E-13	0.00	0.0327	1.70	1.92	0.29	2.69	10.96131	3.53020	3.00000	23,212.99
		A0307	15.0	16.0	7	83	10	2.99E-04	4.22E-11	0.00	0.0602	3.60	1.67	0.38	2.71	5.67118	2.75893	3.00000	938.28
	DP-7	A0101	0.7	2.0	54	36	10	1.38E-05	5.76E-12	0.00	0.0462	2.40	1.92	0.29	2.69	6.39672	2.52583	3.00000	641.67
		A0105	16.5	18.0	70	23	7	2.82E-04	2.09E-10	0.00	0.0308	1.60	1.92	0.29	2.69	3.98105	1.66448	3.00000	162.91
		A0109	28.4	30.0	25	62	13	2.82E-04	1.29E-09	0.00	0.0593	3.70	1.60	0.41	2.73	3.98105	1.66448	3.00000	101.01
1100-1	BAP-1	A1002S	2.2	4.2	26	55	19	1.38E-05	3.23E-09	0.00	0.1427	8.90	1.60	0.40	2.68	6.39672	2.52583	3.00000	88.08
		A1006S	6.1	6.8	54	27	19	8.88E-04	7.76E-09	0.00	0.0904	4.70	1.92	0.29	2.69	1.82678	3.55379	3.00000	109.71
		A1009S	7.8	8.8	42	37	21	5.77E-04	4.14E-11	0.00	0.0558	2.90	1.92	0.29	2.69	10.96131	3.53020	3.00000	3,522.93
		A1013S	13.4	13.9	44	43	13	5.77E-04	1.11E-10	0.00	0.0616	3.20	1.92	0.29	2.69	10.96131	3.53020	3.00000	2,488.76
		A1015S	16.3	17.5	65	28	7	1.21E-03	9.07E-11	0.00	0.0442	2.30	1.92	0.29	2.69	2.53447	2.89360	3.00000	562.52
1100-2	DP-4	A0402S	0.8	1.4	34	55	11	1.78E-04	1.00E-15	0.00	0.0154	0.80	1.92	0.29	2.69	4.77236	2.93040	3.00000	25,050.39
		A0404S	1.9	3.1	31	51	18	2.99E-04	6.18E-10	0.00	0.0616	3.20	1.92	0.29	2.69	5.67118	2.75893	3.00000	393.58
		A0406S	3.3	5.1	[redacted]														
		A0410S	10.7	12.4	64	28	8	1.78E-04	2.44E-11	0.00	0.0481	2.50	1.92	0.29	2.69	4.77236	2.93040	3.00000	888.60
		A0412S	16.0	17.0	60	32	8	1.38E-05	1.49E-11	0.00	0.0519	2.70	1.92	0.29	2.69	6.39672	2.52583	3.00000	476.55
	DP-5	A0503S	2.6	3.6	48	39	13	8.88E-04	5.89E-11	0.00	0.0558	2.90	1.92	0.29	2.69	1.82678	3.55379	3.00000	610.21
		A0505S	6.6	7.1	35	48	17	2.24E-04	1.24E-08	0.00	0.1039	5.40	1.92	0.29	2.69	2.05436	3.33689	3.00000	60.46
		A0509S	10.0	11.0	48	45	7	5.73E-04	6.24E-09	0.00	0.0846	4.40	1.92	0.29	2.69	11.58480	3.18989	3.00000	564.56
		A0512S	15.0	15.7	33	60	7	1.21E-03	5.83E-08	0.00	0.0923	4.80	1.92	0.29	2.69	2.53447	2.89360	3.00000	66.93
		A0513S	16.2	18.0	4	93	3	2.99E-04	2.15E-10	0.00	0.0703	4.20	1.67	0.37	2.65	5.67118	2.75893	3.00000	553.68
	DP-6	A0603S	0.5	2.0	42	45	13	5.77E-04	5.77E-15	0.00	0.0231	1.20	1.92	0.29	2.69	10.96131	3.53020	3.00000	79,384.61
		A0604S	2.5	3.7	36	42	22	5.77E-04	1.04E-13	0.00	0.0308	1.60	1.92	0.29	2.69	10.96131	3.53020	3.00000	28,752.63
		A0607S	4.2	5.7	39	41	20	1.38E-05	6.30E-10	0.00	0.0827	4.30	1.92	0.29	2.69	6.39672	2.52583	3.00000	147.11
		A0609S	7.9	9.0	54	38	8	1.21E-03	9.07E-11	0.00	0.0442	2.30	1.92	0.29	2.69	2.53447	2.89360	3.00000	562.52
		A0611S	12.8	13.8	32	61	7	1.21E-03	1.65E-09	0.00	0.0616	3.20	1.92	0.29	2.69	2.53447	2.89360	3.00000	216.34
		A0614S	16.3	17.3	14	79	7	5.73E-04	7.25E-12	0.00	0.0535	3.20	1.67	0.37	2.66	11.58480	3.18989	3.00000	5,621.29
	DP-9	A1102S	2.6	3.6	43	40	17	1.38E-05	1.10E-11	0.00	0.0500	2.60	1.92	0.29	2.69	6.39672	2.52583	3.00000	524.22
		A1104S	6.75	7.1	51	34	15	5.77E-04	1.88E-09	0.00	0.1154	7.20	1.60	0.41	2.69	10.96131	3.53020	3.00000	922.71
		A1108S	9.0	9.2	23	69	8	1.21E-03	5.46E-09	0.00	0.0731	3.80	1.92	0.30	2.73	2.53447	2.89360	3.00000	145.97
		A1109S	9.2	11.5	25	70	5	2.99E-04	1.08E-10	0.00	0.0653	3.90	1.67	0.37	2.66	5.67118	2.75893	3.00000	691.36
		A1110S	9.2	11.5	21	72	7	2.99E-04	6.36E-07	0.00	0.1807	10.80	1.67	0.37	2.66	5.67118	2.75893	3.00000	41.62
		A1112S	13.5	14.5	18	76	6	2.99E-04	1.73E-08	0.00	0.0885	4.60	1.92	0.28	2.66	5.67118	2.75893	3.00000	133.67
		A1113S	15.5	16.5	26	66	8	5.73E-04	1.45E-11	0.00	0.0641	4.00	1.60	0.41	2.73	11.58480	3.18989	3.00000	4,438.91
		A1117S	21.8	22.1	45	49	6	2.82E-04	1.12E-08	0.00	0.0577	3.00	1.92	0.29	2.69	3.98105	1.66448	3.00000	57.22
		A1120S	25.0	26.0	69	24	7	1.21E-03	3.71E-10	0.00	0.0519	2.70	1.92	0.29	2.69	2.53447	2.89360	3.00000	353.70
		A1122S	31.1	32.1	62	28	10	2.82E-04	3.53E-09	0.00	0.0481	2.50	1.92	0.29	2.69	3.98105	1.66448	3.00000	77.51
		A1124S	35.5	36.8	60	29	11	5.77E-04	4.80E-10	0.00	0.0712	3.70	1.92	0.29	2.69	10.96131	3.53020	3.00000	1,490.72
1100-3	DP-1	A0902S	4.0	5.1	46	42	12	1.21E-03	1.89E-10	0.00	0.0481	2.50	1.92	0.29	2.69	2.53447	2.89360	3.00000	441.93
		A0905S	6.9	7.9	48	42	10	1.78E-04	1.70E-11	0.00	0.0462	2.40	1.92	0.29	2.69	4.77236	2.93040	3.00000	1,001.51
		A0908S	11.9	12.9	15	73	12	1.38E-05	6.46E-11	0.00	0.0830	4.90	1.69	0.38	2.73	6.39672	2.52583	3.00000	300.50
		A0911S	15.5	16.5	2	91	7	5.73E-04	2.04E-09	0.00	0.0971	5.80	1.67	0.37	2.65	11.58480	3.18989	3.00000	826.25
	DP-2	A0802S	2.0	3.5	39	51	10	1.21E-03	6.03E-13	0.00	0.0250	1.30	1.92	0.29	2.69	2.53447	2.89360	3.00000	2,931.74
		A0804S	6.5	8.0	54	36	10	2.82E-04	5.74E-09	0.00	0.0519	2.70	1.92	0.29	2.69	3.98105	1.66448	3.00000	68.19

Table 6-2: VADOSE ZONE MODELING PARAMETERS BROOKS-COREY MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Soil Conductivity at Lab Saturation 7 Ksat (cm/s)	In-Situ Soil Conduct. K (cm/sec)	Residual Moisture 5 (THETA r)	Moisture Values In-Situ Moisture Content (THETA)	Moisture Weight % Measured 4	Bulk Density 1	Estimated Soil Porosity = Saturated Moisture Content 3 (THETA s)	SpG2	Brooks-Corey Parameters 6 he	b	b'	Calculated Suction Head 8 (cm) (h)
		A0806S	8.5	10.2	9	86	5	1.78E-04	3.27E-11	0.00	0.0647	3.80	1.70	0.37	2.71	4.77236	2.93040	3.00000	806.44
		A0807S	12.6	14.3	10	82	8	5.73E-04	5.41E-11	0.00	0.0664	3.90	1.70	0.37	2.71	11.58480	3.18989	3.00000	2,838.06
	DP-2	A0809S	15.0	16.0	40	47	13	2.82E-04	7.23E-09	0.00	0.0539	2.80	1.92	0.29	2.69	3.98105	1.66448	3.00000	64.18
		A0811S	17.6	20.0	14	79	7	1.21E-03	1.36E-10	0.00	0.0602	3.60	1.67	0.37	2.66	2.53447	2.89360	3.00000	492.42
	DP-3	A0703S	2.3	3.3	41	40	19	8.88E-04	4.00E-13	0.00	0.0289	1.50	1.92	0.29	2.69	11.58480	3.18989	3.00000	17,480.08
		A0706S	7.1	8.1	60	35	5	3.64E-03	2.39E-09	0.00	0.0481	2.50	1.92	0.29	2.69	9.92654	2.49085	3.00000	843.87
		A0707S	10.1	10.8	14	81	5	2.99E-04	3.03E-10	0.00	0.0736	4.40	1.67	0.37	2.66	5.67118	2.75893	3.00000	495.64
		A0710S	13.2	14.3	3	94	3	2.99E-04	7.31E-11	0.00	0.0619	3.70	1.67	0.37	2.65	5.67118	2.75893	3.00000	785.47
		A0711S	15.2	16.0	5	93	2	2.99E-04	6.41E-11	0.00	0.0645	3.90	1.65	0.39	2.71	5.67118	2.75893	3.00000	819.76
	DP-8	A1202S	2.5	3.7	41	47	12	3.64E-03	4.05E-11	0.00	0.0289	1.50	1.92	0.29	2.69	9.92654	2.49085	3.00000	3,012.09
		A1207S	7.7	8.9	42	49	9	5.73E-04	6.05E-12	0.00	0.0404	2.10	1.92	0.29	2.69	11.58480	3.18989	3.00000	5,976.00
		A1212S	15.1	16.1	54	40	6	2.82E-04	8.60E-10	0.00	0.0385	2.00	1.92	0.29	2.69	3.98105	1.66448	3.00000	112.37
		A1214S	18.3	18.7	34	56	10	2.82E-04	1.17E-09	0.00	0.0404	2.10	1.92	0.29	2.69	3.98105	1.66448	3.00000	103.61
		A1215S	20.5	22.2	17	73	10	1.21E-03	4.99E-12	0.00	0.0423	2.50	1.69	0.38	2.73	2.53447	2.89360	3.00000	1,461.80
		A1216S	23.7	26.4	19	73	8	1.21E-03	2.74E-11	0.00	0.0502	3.00	1.67	0.37	2.66	2.53447	2.89360	3.00000	834.56
		A1218S	26.4	27.4	54	33	13	5.77E-04	9.84E-13	0.00	0.0385	2.00	1.92	0.29	2.69	10.96131	3.53020	3.00000	13,078.73
		A1220S	30.2	31.4	54	39	7	2.82E-04	2.08E-09	0.00	0.0442	2.30	1.92	0.29	2.69	3.98105	1.66448	3.00000	89.05
HRL	HRL-2	A1803S	3.4	4.8	51	35	14	5.77E-04	8.09E-11	0.00	0.0596	3.10	1.92	0.29	2.69	10.96131	3.53020	3.00000	2,783.92
		A1806S	8.0	8.9	36	54	10	2.82E-04	4.41E-10	0.00	0.0346	1.80	1.92	0.29	2.69	3.98105	1.66448	3.00000	133.91
		A1809S	12.5	13.5	54	34	12	5.77E-04	1.92E-13	0.00	0.0327	1.70	1.92	0.29	2.69	10.96131	3.53020	3.00000	23,212.99
		A1811S	16.5	17.6	58	29	13	5.77E-04	1.92E-13	0.00	0.0327	1.70	1.92	0.29	2.69	10.96131	3.53020	3.00000	23,212.99
		A1813S	20.0	21.7	48	35	17	5.77E-04	4.02E-12	0.00	0.0442	2.30	1.92	0.29	2.69	10.96131	3.53020	3.00000	7,985.28
	HRL-3	A2003S	2.8	4.4	54	34	12	2.82E-04	7.73E-09	0.00	0.0544	2.83	1.92	0.29	2.69	3.98105	1.66448	3.00000	63.06
		A2006S	8.0	9.3	68	24	8	5.77E-04	5.82E-11	0.00	0.0577	3.00	1.92	0.29	2.69	10.96131	3.53020	3.00000	3,125.56
		A2008S	13.3	14.5	47	45	8	2.82E-04	6.01E-07	0.00	0.1083	5.63	1.92	0.29	2.69	3.98105	1.66448	3.00000	20.07
		A2011S	17.6	18.8	61	29	10	5.77E-04	4.14E-11	0.00	0.0558	2.90	1.92	0.29	2.69	10.96131	3.53020	3.00000	3,522.93
		A2013S	22.0	23.2	68	25	7	5.77E-04	3.35E-10	0.00	0.0687	3.57	1.92	0.29	2.69	10.96131	3.53020	3.00000	1,691.35
	HRL-4	A2203S	3.2	4.6	56	34	10	3.64E-03	2.78E-08	0.00	0.0654	3.40	1.92	0.29	2.69	9.92654	2.49085	3.00000	392.33
		A2206S	8.2	9.7	66	24	10	5.77E-04	6.16E-12	0.00	0.0462	2.40	1.92	0.29	2.69	10.96131	3.53020	3.00000	6,871.32
		A2209S	13.6	14.4	37	48	15	2.82E-04	1.68E-08	0.00	0.0616	3.20	1.92	0.29	2.69	3.98105	1.66448	3.00000	51.39
		A2211S	17.4	18.9	59	28	13	5.77E-04	2.04E-12	0.00	0.0414	2.15	1.92	0.29	2.69	10.96131	3.53020	3.00000	10,131.82
		A2213S	21.5	23.5	71	22	7	5.77E-04	9.20E-11	0.00	0.0604	3.14	1.92	0.29	2.69	10.96131	3.53020	3.00000	2,660.73
	HRL-5	A1503S	3.8	6.0	60	35	5	1.78E-04	2.23E-07	0.00	0.1347	7.00	1.92	0.29	2.69	4.77236	2.93040	3.00000	43.49
		A1505S	8.6	9.4	53	37	10	3.64E-03	5.46E-08	0.00	0.0712	3.70	1.92	0.29	2.69	9.92654	2.49085	3.00000	317.82
		A1508S	11.8	13.1	59	28	13	5.77E-04	2.04E-12	0.00	0.0414	2.15	1.92	0.29	2.69	10.96131	3.53020	3.00000	10,131.82
		A1511S	15.5	16.0	51	30	19	5.77E-04	9.19E-14	0.00	0.0304	1.58	1.92	0.29	2.69	10.96131	3.53020	3.00000	30,058.18
		A1514S	21.9	22.8	48	32	20	5.77E-04	1.04E-13	0.00	0.0308	1.60	1.92	0.29	2.69	10.96131	3.53020	3.00000	28,752.63
	HRL-6	A1604S	7.1	9.4	65	33	2	1.78E-04	4.10E-04	0.00	0.3174	16.50	1.92	0.29	2.70	4.77236	2.93040	3.00000	3.62
		A1606S	9.4	11.6	75	21	4	2.82E-04	3.86E-07	0.00	0.1010	5.25	1.92	0.29	2.69	3.98105	1.66448	3.00000	22.54
		A1609S	16.2	18.5	80	18	2	2.82E-04	1.10E-05	0.00	0.1731	9.00	1.92	0.29	2.70	3.98105	1.66448	3.00000	9.33
		A1610S	18.5	20.8	80	18	2	2.82E-04	1.10E-05	0.00	0.1731	9.00	1.92	0.29	2.70	3.98105	1.66448	3.00000	9.33
		A1611S	21.5	23.0	51	35	14	5.77E-04	9.29E-12	0.00	0.0481	2.50	1.92	0.29	2.69	10.96131	3.53020	3.00000	5,949.14
		A1614S	24.2	25.0	32	41	27	5.77E-04	6.22E-14	0.00	0.0292	1.52	1.92	0.29	2.69	10.96131	3.53020	3.00000	34,460.19
		A1615S	25.0	25.2	36	38	26	8.88E-04	5.73E-14	0.00	0.0281	1.46	1.92	0.29	2.69	18.26784	3.55379	3.00000	69,930.69
		A1616S	25.8	27.8	74	20	6	5.77E-04	1.66E-10	0.00	0.0641	3.33	1.92	0.29	2.69	10.96131	3.53020	3.00000	2,162.36
	HRL-7	A2302S	2.7	4.3	70	23	7	3.64E-03	2.14E-08	0.00	0.0633	3.29	1.92	0.29	2.69	9.92654	2.49085	3.00000	425.82
		A2305S	7.3	8.4	58	30	12	5.77E-04	9.29E-12	0.00	0.0481	2.50	1.92	0.29	2.69	10.96131	3.53020	3.00000	5,949.14
		2309S	11.2	12.2	58	30	12	3.64E-03	2.39E-09	0.00	.0481	2.50	1.92	0.29	2.69	9.92654	2.49085	3.0000	843.87
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 6-2: VADOSE ZONE MODELING PARAMETERS
BROOKS-COREY MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Soil Conductivity at Lab Saturation 7 Ks(cm/s)	In-Situ Soil Conduct. K(cm/sec)	Residual Moisture 5 (THETA r)	Moisture Values In-Situ Moisture Content (THETA)	Moisture Weight % Measured 4	Bulk Density 1	Estimated Soil Porosity = Saturated Moisture Content 3 (THETA s)	SpG2	Brooks-Corey Parameters 6 he	b	b'	Calculated Suction Head 8 (cm) (h)
		A2313S	19.0	20.0	56	29	15	5.77E-04	6.88E-13	0.00	0.0371	1.93	1.92	0.29	2.69	10.96131	3.53020	3.00000	14,831.58
	HRL-8	A1403S	2.5	4.4	79	16	5	5.77E-04	1.11E-10	0.00	0.0616	3.20	1.92	0.29	2.69	10.96131	3.53020	3.00000	2,488.75
		A1405S	7.5	8.2	24	54	22	1.38E-05	7.33E-12	0.00	0.0471	2.45	1.92	0.28	2.68	6.39672	2.52583	3.00000	594.90
	HRL-8	A1408S	10.9	12.8	64	21	15	8.88E-04	3.75E-14	0.00	0.0269	1.40	1.92	0.29	2.69	1.82678	3.55379	3.00000	8,117.74
		A1410S	17.6	18.8	66	24	10	1.38E-05	5.76E-12	0.00	0.0462	2.40	1.92	0.29	2.69	6.39672	2.52583	3.00000	641.67
		A1413S	22.6	23.1	48	29	23	5.77E-04	9.43E-15	0.00	0.0242	1.26	1.92	0.29	2.69	10.96131	3.53020	3.00000	66,824.21
HRL	HRL-9	A1703S	2.8	3.7	58	32	10	2.82E-04	1.68E-08	0.00	0.0616	3.20	1.92	0.29	2.69	3.98105	1.66448	3.00000	51.39
		A1705S	5.0	5.8	51	31	18	5.77E-04	2.16E-13	0.00	0.0331	1.72	1.92	0.29	2.69	10.96131	3.53020	3.00000	22,274.06
		A1708S	9.4	10.4	65	25	10	5.77E-04	9.29E-12	0.00	0.0481	2.50	1.92	0.29	2.69	10.96131	3.53020	3.00000	5,949.14
		A1711S	14.2	15.2	69	21	10	5.77E-04	1.61E-12	0.00	0.0404	2.10	1.92	0.29	2.69	10.96131	3.53020	3.00000	11,009.39
		A1713S	20.4	21.7	74	19	7	2.82E-04	5.88E-09	0.00	0.0521	2.71	1.92	0.29	2.69	3.98105	1.66448	3.00000	67.77
	HRL-10	A1907S	9.1	11.4	73	21	6	2.82E-04	3.53E-09	0.00	0.0481	2.50	1.92	0.29	2.69	3.98105	1.66448	3.00000	77.51
		A1908S	11.4	13.7	54	37	9	2.82E-04	1.57E-09	0.00	0.0423	2.20	1.92	0.29	2.69	3.98105	1.66448	3.00000	95.89
		A1910S	16.9	17.8	32	51	17	5.77E-04	4.80E-10	0.00	0.0712	3.70	1.92	0.29	2.69	10.96131	3.53020	3.00000	1,490.72
		A1911S	17.8	20.1	63	30	7	2.82E-04	1.12E-08	0.00	0.0577	3.00	1.92	0.29	2.69	3.98105	1.66448	3.00000	57.22
		A1913S	27.9	30.3	81	17	2	3.64E-03	4.39E-08	0.00	0.0693	3.60	1.92	0.29	2.69	9.92654	2.49085	3.00000	340.27
Monitoring Wells	MW-1	1	10.5	12.1	73	22	5	5.77E-04	9.43E-15	0.00	0.0242	1.26	1.92	0.29	2.69	10.96131	3.53020	3.00000	66,824.21
		2	21.0	22.0	63	33	4	2.28E-04	4.04E-08	0.00	0.0731	3.80	1.92	0.29	2.69	3.98105	1.66448	3.00000	38.61
		3	29.3	31.3	60	35	5	2.28E-04	4.98E-09	0.00	0.0525	2.73	1.92	0.29	2.69	3.98105	1.66448	3.00000	66.95
		4	34.0	35.0	86	13	1	1.79E-04	1.45E-12	0.00	0.0346	1.77	1.95	0.28	2.72	4.77236	2.93040	3.00000	2,261.11
		5	40.0	41.7	32	64	4	5.73E-04	3.62E-09	0.00	0.0806	4.19	1.92	0.29	2.70	11.58480	3.18989	3.00000	679.51
	MW-2	1	11.5	12.8	58	36	6	1.21E-03	5.67E-11	0.00	0.0419	2.18	1.92	0.29	2.69	2.53447	2.89360	3.00000	656.86
		2	19.0	20.0	60	33	7	1.21E-03	8.64E-12	0.00	0.0339	1.76	1.92	0.29	2.69	2.53447	2.89360	3.00000	1,220.16
	MW-3	A2403	2.5	4.1	14	63	23	8.88E-04	1.98E-10	0.00	0.0871	5.43	1.60	0.40	2.65	1.82678	3.55379	3.00000	398.68
		A2406	7.4	8.8	65	27	8	1.38E-05	1.46E-11	0.00	0.0498	2.59	1.92	0.28	2.65	6.39672	2.52583	3.00000	480.46
		A2408	15.1	16.9	77	18	5	2.82E-04	4.28E-09	0.00	0.0477	2.48	1.92	0.28	2.65	3.98105	1.66448	3.00000	73.69
		A2410	23.2	24.8	45	45	10	5.73E-04	9.82E-11	0.00	0.0523	2.72	1.92	0.28	2.65	11.58480	3.18989	3.00000	2,316.75
		A2412	35.3	37.0	68	24	8	2.82E-04	4.29E-08	0.00	0.0687	3.57	1.92	0.28	2.65	3.98105	1.66448	3.00000	40.19
		A2414	36.6	39.2	60	23	17	5.77E-04	2.59E-09	0.00	0.0810	4.21	1.92	0.28	2.65	10.96131	3.53020	3.00000	825.28
	MW-4	1	8.5	9.5	48	46	6	1.21E-03	2.57E-11	0.00	0.0385	2.00	1.92	0.29	2.69	2.53447	2.90226	3.00000	857.66
		2	16.0	17.0	40	55	5	2.82E-04	1.06E-08	0.00	0.0577	3.00	1.92	0.29	2.70	3.98105	1.66448	3.00000	58.10
		3	31.0	32.0	65	32	3	1.21E-03	4.82E-11	0.00	0.0416	2.16	1.92	0.29	2.70	2.53447	2.89360	3.00000	692.80
	MW-5	1	2.4	2.5	2	94	4	5.73E-04	5.39E-13	0.00	0.0403	2.41	1.67	0.37	2.65	11.58480	3.18989	3.00000	13,607.25
		2	5.8	6.0	54	41	5	2.99E-04	5.52E-11	0.00	0.0464	2.41	1.92	0.29	2.69	5.67118	2.75893	3.00000	860.49
		4	18.5	19.0	39	57	4	2.82E-04	1.14E-09	0.00	0.0406	2.11	1.92	0.29	2.70	3.98105	1.66448	3.00000	104.37
		5	34.5	35.0	75	22	3	2.82E-04	1.22E-10	0.00	0.0283	1.47	1.92	0.29	2.69	3.98105	1.66448	3.00000	187.59
		6	48.0	48.5	72	22	6	5.77E-04	3.93E-09	0.00	0.0877	4.56	1.92	0.29	2.69	10.96131	3.53020	3.00000	712.83
	MW-6	1	24.0	25.0	55	33	12	5.77E-04	5.28E-13	0.00	0.0400	2.08	1.92	0.32	2.81	10.96131	3.53020	3.00000	16,276.84
		2	43.0	44.4	80	19	1	5.73E-04	3.38E-09	0.00	0.0800	4.16	1.92	0.29	2.70	11.58480	3.18989	3.00000	695.26
	MW-8	1	3.5	4.0	58	37	5	2.82E-04	4.90E-10	0.00	0.0352	1.83	1.92	0.29	2.69	3.98105	1.66448	3.00000	130.28
	MW-9	1	4.6	5.2	51	36	13	5.77E-04	6.87E-11	0.00	0.0587	3.05	1.92	0.29	2.69	10.96131	3.53020	3.00000	2,948.40
		2			59	33	8	2.41E-05	1.62E-16	0.00	0.0317	1.65	1.92	0.29	2.69	6.57549	4.34915	3.00000	93,698.02
		3	14.1	15.2	23	73	4	2.99E-04	7.06E-12	0.00	0.0474	2.83	1.67	0.37	2.66	5.67118	2.75893	3.00000	1,674.80
	MW-10	1	9.5	10.5	22	73	5	2.99E-04	2.22E-12	0.00	0.0413	2.47	1.67	0.37	2.66	5.67118	2.75893	3.00000	2,437.74
		2	14.5	15.0	65	26	9	5.77E-04	4.74E-13	0.00	0.0358	1.86	1.92	0.29	2.69	10.96131	3.53020	3.00000	16,897.69

Table 6-2: VADOSE ZONE MODELING PARAMETERS BROOKS-COREY MODEL

Operable Subunit	Borehole Number	Sample Number	Sample Depth From	Sample Depth To	Soil Gradations LAB % G	% S	% M	Soil Conductivity at Lab Saturation 7 Ks(cm/s)	In-Situ Soil Conduct. Kl(cm/sec)	Residual Moisture 5 (THETA r)	Moisture Values In-Situ Moisture Content (THETA)	Moisture Weight % Measured 4	Bulk Density 1	Estimated Soil Porosity = Saturated Moisture Content 3 (THETA s)	SpG2	Brooks-Corey Parameters 6 he	b	b'	Calculated Suction Head 8 (cm) (h)
		3	18.6	19.0	68	26	6	1.78E-04	9.96E-12	0.00	0.0435	2.26	1.92	0.29	2.69	4.77236	2.93040	3.00000	1,194.40
	MW-11	1	8.6	9.4	51	46	3	2.99E-04	1.83E-12	0.00	0.0314	1.63	1.92	0.29	2.70	5.67118	2.75893	3.00000	2,596.00
	MW-12	1	1.0	1.5	0	98	2	5.77E-04	7.92E-11	0.00	0.0686	4.10	1.67	0.37	2.65	11.58480	3.18989	3.00000	2,498.32
		2	3.5	4.0	9	68	23	8.88E-04	1.18E-09	0.00	0.1068	6.66	1.60	0.41	2.70	1.82678	3.55379	3.00000	213.03
	MW-12	3	5.5	6.0	9	82	9	1.80E-03	3.71E-12	0.00	0.0336	2.03	1.65	0.39	2.71	13.14579	2.57202	3.00000	7,274.60
		4	6.5	7.0	52	42	6	1.80E-03	1.08E-10	0.00	0.0371	1.93	1.92	0.29	2.69	13.14579	2.57202	3.00000	2,513.00
		5	7.0	7.5	26	71	3	2.41E-05	1.65E-17	0.00	0.0348	2.08	1.67	0.38	2.70	6.57549	4.34915	3.00000	*********
		6	10.0	10.5	61	33	6	2.82E-04	8.45E-09	0.00	0.0552	2.87	1.92	0.29	2.69	3.98105	1.66448	3.00000	61.60
		7	11.5	12.0	46	50	4	1.78E-04	2.50E-11	0.00	0.0487	2.53	1.92	0.29	2.70	4.77236	2.93040	3.00000	881.50
		8	16.5	17.0	66	27	7	1.38E-05	1.02E-10	0.00	0.0660	3.43	1.92	0.29	2.69	6.39672	2.52583	3.00000	260.38
		9	26.5	27.0	72	23	5	1.80E-03	1.87E-09	0.00	0.0527	2.74	1.92	0.29	2.69	13.14579	2.57202	3.00000	1,020.35
		10	33.5	34.0	73	22	5	1.38E-05	9.25E-10	0.00	0.0868	4.51	1.92	0.29	2.69	6.39672	2.52583	3.00000	130.41
Monitoring Wells	MW-13	1	9.5	10.0	62	35	3	1.78E-04	5.75E-11	0.00	0.0535	2.78	1.92	0.29	2.70	4.77236	2.93040	3.00000	668.80
		2	13.0	13.5	47	51	2	5.73E-04	1.47E-11	0.00	0.0448	2.33	1.92	0.29	2.70	11.58480	3.18989	3.00000	4,417.38
		3	14.0	14.5	63	30	7	2.82E-04	2.20E-09	0.00	0.0446	2.32	1.92	0.29	2.69	3.98105	1.66448	3.00000	87.77
		4	17.5	18.0	86	12	2	2.82E-04	1.17E-08	0.00	0.0574	2.94	1.95	0.28	2.72	3.98105	1.66448	3.00000	56.61
		5	25.5	26.0	77	19	4	1.38E-05	1.00E-14	0.00	0.0210	1.09	1.92	0.29	2.69	6.39672	2.52583	3.00000	4,711.16
	MW-14	1	7.6	8.8	53	39	8	1.38E-05	9.08E-10	0.00	0.0866	4.50	1.92	0.29	2.69	6.39672	2.52583	3.00000	131.15
		2	10.8	11.5	50	44	6	2.82E-04	6.91E-09	0.00	0.0535	2.78	1.92	0.29	2.69	3.98105	1.66448	3.00000	64.95
		3	20.5	21.0	82	16	2	2.82E-04	3.14E-09	0.00	0.0467	2.39	1.95	0.28	2.72	3.98105	1.66448	3.00000	79.92
		4	21.5	22.0	58	31	11	1.38E-05	6.68E-14	0.00	0.0265	1.38	1.92	0.29	2.69	6.39672	2.52583	3.00000	2,696.27
	MW-15	1	5.0	7.0	54	38	8	1.78E-04	1.46E-12	0.00	0.0350	1.82	1.92	0.29	2.69	4.77236	2.93040	3.00000	2,252.76
		2	9.0	10.0	55	40	5	2.82E-04	1.14E-09	0.00	0.0402	2.09	1.92	0.29	2.69	3.98105	1.66448	3.00000	104.43
		3	14.5	15.0	73	22	5	1.80E-03	5.53E-10	0.00	0.0454	2.36	1.92	0.29	2.69	13.14579	2.57202	3.00000	1,498.01
		4	19.5	20.0	72	24	4	1.80E-03	6.97E-11	0.00	0.0352	1.83	1.92	0.29	2.69	13.14579	2.57202	3.00000	2,881.52
		5	24.7	25.2	68	22	10	5.77E-04	1.96E-14	0.00	0.0256	1.33	1.92	0.28	2.67	10.96131	3.53020	3.00000	51,657.58
	MW-17	2	15.0	16.0	72	23	5	2.82E-04	3.56E-10	0.00	0.0335	1.74	1.92	0.29	2.69	3.98105	1.66448	3.00000	141.68
		5	30.0	31.0	0	88	12	2.41E-05	2.01E-09	0.00	0.1341	6.97	1.92	0.30	2.74	6.57549	4.34915	3.00000	215.92
		6	35.0	36.0	28	65	7	2.82E-04	9.96E-10	0.00	0.0512	3.06	1.67	0.37	2.66	3.98105	1.66448	3.00000	108.11
		7	37.0	38.0	52	41	7	2.82E-04	5.80E-06	0.00	0.1401	7.28	1.92	0.26	2.59	3.98105	1.66448	3.00000	11.05
Sum					************			1.07E-01	4.41E-04	0.00	9.89	534.54	319.13	51.32	457.12	1204.43	*********	*********	*********
n					168	168	168	168	168	168	168	168	168	168	168	168	168	168	168
Average					50	42	9	6.38E-04	2.62E-06	0.00	0.06	3.18	1.90	0.31	2.72	7.16921	2.79482	3.01786	7,346.95

NOTES:

1. Bulk density values estimated from table 3.5, Geotechnical Engineering Analysis and Design, R.E. Hunt.
2. Specific gravity values from lab testing were used for all similarly classified soils; the average of measured Silty Sandy Gravel specific gravity analyses were used in the similar soil type where no testing was performed; all other values were estimated.
3. Soil porosity calculated from (1-(bulk density/specific gravity)). Soil porosity is assumed equal to the saturated moisture content.
4. Soil in-situ moisture calculated from (((bulk density * weight % measured)/0.998)/100). Units in cubic cm./cubic cm. 0.998 = grams water per cubic cm
5. Soil residual moisture value of zero was the recommended value for sands and gravels per Mr. Michael Fayer, PNL.
6. Brooks-Corey parameters were derived from converting Van Genuchten functions using the formulas:
   he = 1/a
   b = 1/(n-1)
   b' = (1+l) where l is taken as 2.0 for the Burdine conductivity model.
7. Soil Conductivity at Lab Saturation was obtained in the same method as the van Genuchten parameters (see note 6).
8. Calculated suction head was obtained using an HP28S calculator and the formula;
   h = he/(THETA/THETA s)^b
   Suction head is the absolute value of soil matr[illegible]tential.

TABLE 6-3: UNSAT-H MODEL CONSTRUCTION
based on monitoring well MW-15 located at the Horn Rapids Landfill

Node Number	Node Depth (cm) "Z(n)"	Node Depth (ft)	Initial Elevation Head (cm) "H(n)"	Soil Type "MAT(n)"	Plant Root Growth "NTROOT(n)"
1	0.00	0.0000	853.00	1	1
2	0.10	0.0033	852.90	1	1
3	0.20	0.0066	852.80	1	1
4	0.30	0.0098	852.70	1	1
5	0.40	0.0131	852.60	1	1
6	0.50	0.0164	852.50	1	1
7	1.00	0.0328	852.00	1	1
8	3.00	0.0984	850.00	1	1
9	5.00	0.1640	848.00	1	1
10	15.00	0.4921	838.00	1	1
11	25.00	0.8202	828.00	1	1
12	40.00	1.3123	813.00	1	1
13	60.00	1.9685	793.00	1	1
14	80.00	2.6247	773.00	1	65
15	100.00	3.2808	753.00	1	90
16	120.00	3.9370	733.00	1	120
17	130.00	4.2651	723.00	1	135
18	150.00	4.9213	703.00	1	165
19	160.00	5.2493	693.00	1	243
20	170.00	5.5774	683.00	1	321
21	177.00	5.8071	676.00	1	362
22	179.00	5.8727	674.00	1	364
23	181.00	5.9383	672.00	1	365
24	182.50	5.9875	670.50	1	365
25	182.70	5.9941	670.30	1	365
26	182.90	6.0007	670.10	1	365
27	183.00	6.0039	670.00	2	365
28	183.10	6.0072	669.90	2	365
29	183.30	6.0138	669.70	2	365
30	183.50	6.0203	669.50	2	365
31	184.00	6.0367	669.00	2	365
32	186.00	6.1024	667.00	2	365
33	188.00	6.1680	665.00	2	365
34	195.00	6.3976	658.00	2	365
35	205.00	6.7257	648.00	2	365
36	220.00	7.2178	633.00	2	365
37	240.00	7.8740	613.00	2	365
38	260.00	8.5302	593.00	2	365
39	280.00	9.1864	573.00	2	365
40	300.00	9.8425	553.00	2	365
41	310.00	10.1706	543.00	2	365
42	320.00	10.4987	533.00	2	365
43	329.00	10.7940	524.00	2	365
44	331.00	10.8596	522.00	2	365
45	333.00	10.9252	520.00	2	365
46	334.50	10.9744	518.50	2	365
47	334.70	10.9810	518.30	2	365
48	334.90	10.9875	518.10	2	365
49	335.00	10.9908	518.00	3	365
50	335.10	10.9941	517.90	3	365
51	335.30	11.0007	517.70	3	365
52	335.50	11.0072	517.50	3	365
53	336.00	11.0236	517.00	3	365
54	338.00	11.0892	515.00	3	365
55	340.00	11.1549	513.00	3	365

TABLE 6–3: UNSAT–H MODEL CONSTRUCTION
based on monitoring well MW–15 located at the Horn Rapids Landfill

Node Number	Node Depth (cm) "Z(n)"	Node Depth (ft)	Initial Elevation Head (cm) "H(n)"	Soil Type "MAT(n)"	Plant Root Growth "NTROOT(n)"
56	350.00	11.4829	503.00	3	365
57	360.00	11.8110	493.00	3	365
58	375.00	12.3032	478.00	3	365
59	395.00	12.9593	458.00	3	365
60	415.00	13.6155	438.00	3	365
61	455.00	14.9278	398.00	3	365
62	475.00	15.5840	378.00	3	365
63	510.00	16.7323	343.00	3	365
64	550.00	18.0446	303.00	3	365
65	585.00	19.1929	268.00	3	365
66	625.00	20.5053	228.00	3	365
67	655.00	21.4895	198.00	3	365
68	685.00	22.4738	168.00	3	365
69	705.00	23.1299	148.00	3	365
70	725.00	23.7861	128.00	3	365
71	740.00	24.2782	113.00	3	365
72	750.00	24.6063	103.00	3	365
73	757.00	24.8360	96.00	3	365
74	759.00	24.9016	94.00	3	365
75	761.00	24.9672	92.00	3	365
76	761.50	24.9836	91.50	3	365
77	761.70	24.9902	91.30	3	365
78	761.90	24.9967	91.10	3	365
79	762.00	25.0000	91.00	4	365
80	762.10	25.0033	90.90	4	365
81	762.30	25.0098	90.70	4	365
82	762.50	25.0164	90.50	4	365
83	763.00	25.0328	90.00	4	365
84	765.00	25.0984	88.00	4	365
85	767.00	25.1640	86.00	4	365
86	775.00	25.4265	78.00	4	365
87	785.00	25.7546	68.00	4	365
88	800.00	26.2467	53.00	4	365
89	810.00	26.5748	43.00	4	365
90	820.00	26.9029	33.00	4	365
91	830.00	27.2310	23.00	4	365
92	835.00	27.3950	18.00	4	365
93	840.00	27.5591	13.00	4	365
94	848.00	27.8215	5.00	4	365
95	850.00	27.8871	3.00	4	365
96	852.00	27.9528	1.00	4	365
97	852.50	27.9692	0.50	4	365
98	852.70	27.9757	0.30	4	365
99	852.90	27.9823	0.10	4	365
100	853.00	27.9856	0.00	4	365

Table 6-4 UNSAT-H™ Input Listing, 1 of 2

Parameter Description	Plants Modeled	Plants Not Modeled
Code Run Options:		
Plant Option	On	Off
Lower Boundary Condition	---------- Constant Head ----------	
Profile Orientation	------------ Vertical ------------	
Heat Flow Option	Off	Off
Upper Boundary Condition	------- Calculated Heat Flux ------	
Lower Boundary Condition	-------- Constant Heat Flux -------	
Simulation Years	100	100
Water Application	----- Values Provided as Input ----	
Convective Heat Flow	Off	Off
Evaporation Option (No Plants)	---	On
Evapotranspiration Distribution	-------- Generated by Model -------	
Surface Boundary Condition	Flux	Flux
Meteorological Condition	----- Values Provided as Input ----	
Cloud Cover Condition	-------- Generated by Model -------	
Soil Hydraulic Computation	----------- Brooks-Corey ----------	
Vapor Flow	On	On
Upper Surface Head Limit	---- Constant Upper Head Value ----	
Maximum Soil Head	1.0E5 cm	1.0E5 cm
Minimum Soil Head	1.0E-4 cm	1.0E-4 cm
Tortuosity	0.66	0.66
Average Soil Temperature	288°K	288°K
Vapor Diffusion in Air	$0.24 cm^2/s$	$0.24 cm^2/s$
Number of Soil Types	4	4
Number of Analysis Nodes	100	100
Soil Property Description Options:		
Saturated Soil Water Content	$0.29 cm^3/cm^3$	$0.29 cm^3/cm^3$
Saturated Hydraulic Conductivity (cm/hr)		
Soil #1	0.6408	0.6408
Soil #2	1.0152	1.0152
Soil #3	6.4800	6.4800
Soil #4	2.0772	2.0772
Residual Water Content	0.00	0.00
Conductivity Model	Mualem	Mualem
Initial Conditions:		
Initial Suction Heads	Table 6-6	Table 6-7

Table 6-4 UNSAT-H™ Input Listing, 2 of 2

Parameter Description	Plants Modeled	Plants Not Modeled
Plant Information:		
Leaf Area Index	Off	-----
Root Growth	exponential	-----
PET Partitioning	cheatgrass data	-----
Day of Year; Seed Germination	275	-----
Day of Year Transpiration Ends	180	-----
Coefficients for Root Growth Equation		
a.	1.163	-----
b.	0.129	-----
c.	0.020	-----
Growth Day Roots Reach Each Node	Table 11-4	-----
Wilting Head Value	30,000cm	-----
Head Where Transpiration Starts Decreasing	3000cm	-----
Transpiration Limiting Head	0.10cm	-----
Percent of Bare Ground Surface	70%	100%
Boundary Conditions:		
Surface Albedo	0.25	0.25
Altitude of Study Site	103m	103m
Height of Wind Speed Measurement	3.0m	3.0m
Average Annual Atmospheric Pressure	929mb	929mb
Meteorological Data	----------- Table 11-3 ----------	

Table 6-5 Precipitation Input for the UNSAT-H™ model

	PRECIPITATION			PRECIPITATION			PRECIPITATION	
YEAR	(cm)	(in)	YEAR	(cm)	(in)	YEAR	(cm)	(in)
1	17.0002	6.6930	35	15.3213	6.0320	69	19.8780	7.8260
2	21.2065	8.3490	36	37.1145	14.6120	70	18.8011	7.4020
3	22.7508	8.9570	37	18.7401	7.3780	71	16.7437	6.5920
4	15.8496	6.2400	38	19.5885	7.7120	72	15.1384	5.9600
5	23.2308	9.1460	39	24.1986	9.5270	73	19.6621	7.7410
6	22.2783	8.7710	40	17.2187	6.7790	74	24.4069	9.6090
7	18.0848	7.1200	41	22.8321	8.9890	75	21.9913	8.6580
8	22.0269	8.6720	42	21.1023	8.3080	76	13.4772	5.3060
9	20.4318	8.0440	43	12.3139	4.8480	77	18.3515	7.2250
10	18.4785	7.2750	44	18.8519	7.4220	78	18.4734	7.2730
11	15.7886	6.2160	45	18.7350	7.3760	79	12.4714	4.9100
12	21.8135	8.5880	46	14.9581	5.8890	80	18.0442	7.1040
13	17.4244	6.8600	47	15.0825	5.9380	81	20.0279	7.8850
14	20.9601	8.2520	48	16.8707	6.6420	82	18.8773	7.4320
15	19.5377	7.6920	49	21.8084	8.5860	83	29.9034	11.7730
16	20.1879	7.9480	50	15.5702	6.1300	84	14.7523	5.8080
17	16.7691	6.6020	51	18.3388	7.2200	85	21.8516	8.6030
18	22.8879	9.0110	52	12.2885	4.8380	86	22.2809	8.7720
19	16.8148	6.6200	53	22.2428	8.7570	87	24.9580	9.8260
20	24.1402	9.5040	54	19.9873	7.8690	88	15.8394	6.2360
21	24.7955	9.7620	55	15.4102	6.0670	89	22.7533	8.9580
22	24.3230	9.5760	56	19.1135	7.5250	90	17.1323	6.7450
23	14.7396	5.8030	57	21.2065	8.3490	91	27.4701	10.8150
24	17.1933	6.7690	58	18.9941	7.4780	92	16.3449	6.4350
25	16.8935	6.6510	59	19.3700	7.6260	93	20.9525	8.2490
26	12.8143	5.0450	60	19.5885	7.7120	94	19.3116	7.6030
27	21.2776	8.3770	61	15.0520	5.9260	95	17.7571	6.9910
28	15.9741	6.2890	62	21.3563	8.4080	96	17.0028	6.6940
29	23.5255	9.2620	63	22.0777	8.6920	97	13.4925	5.3120
30	17.7292	6.9800	64	13.9065	5.4750	98	13.2842	5.2300
31	14.1351	5.5650	65	19.0678	7.5070	99	25.0515	9.8628
32	18.8493	7.4210	66	20.2971	7.9910	100	24.3434	9.5840
33	24.6380	9.7000	67	23.6626	9.3160			
34	15.3619	6.0480	68	14.6075	5.7510			

Average:	19.3161	7.6047
Maximum:	37.1145	14.6120
Minimum:	12.2885	4.8380

6.3.1.3 Vegetation Data. Vegetation input was limited to data on cheatgrass cover as outlined in the UNSAT-H™ user's manual (Fayer and Jones, 1990). Deeper rooted vegetation such as sagebrush was ignored for the purposes of the model simulation due to uncertainties related to cover percentage versus the time of the year. The resulting model outputs will, therefore, provide conservative (*i.e.*, overpredict) flux rates at the top of the groundwater table.

Vegetation cover was estimated to be 30 percent, based on a ground surface survey of the 1100-EM-1 sub-units performed in mid-May, 1992. Root distribution with depth was set within the UNSAT-H™ code to the logarithmic option. Cheatgrass germination date and the date when vegetation transpiration ceases were set at days 275 and 180 (day 1 equates to January 1), respectively. Root growth rate and depth of root penetration were input based on cheatgrass data outlined in the UNSAT-H™ manual. Table 6-3 includes a listing of the day of the year when root growth reaches various model nodes (model variable "NTROOT(n)"). Roots were not assumed to extend beyond node number 23; a depth of 181 cm (71.26 in).

6.3.1.4 Initial Conditions. After steady-state drainage conditions were realized utilizing a uniform precipitation value of 17.018 cm/yr (6.700 in/yr), steady-state head values for modeled node points were extracted and used to restart a 100-year model period with new weather model-generated values inserted for each yearly interval encompassing the 100-year timeframe. The 17.018 cm/yr (6.7 in) precipitation amount was selected to use in reaching steady-state conditions because it was very close to the model computed average value of 19.316 cm/yr (7.605 in/yr); and slightly on the dry side. Tables 6-6 and 6-7 present steady-state head values for modeled node points used to begin the 100-year runs with the plant option set on and off, respectively.

6.3.2 Model Results - Plants Modeled

Yearly output for the 100-year model run with the UNSAT-H code plant option enabled and a 30-percent cheatgrass cover assumed is presented in table 6-8. Model results indicate an average groundwater recharge rate of 1.04 cm/yr (0.41 in/yr). This rate can be considered a conservative value (higher recharge rates will be computed) because deeper rooted shrubbery present within all 1100-EM-1 subunits was not included in the model for lack of reliable input values. Model output is graphically illustrated in figures 6-1 through 6-6.

6.3.3 Model Results - Plants Not Modeled

Yearly output for the 100-year run with the UNSAT-H code plant option set off to simulate an unvegetated site is presented in table 6-9. Model results indicate an average groundwater recharge rate of 3.46 cm/yr (1.36 in/yr). This is considered an appropriate value to assume for the Ephemeral Pool subunit for precipitation falling directly onto the existing ground surface. Runoff entering the site from the adjacent asphalt-paved parking area must be added to this amount. The no-plants recharge rate would also be appropriate to assume for short periods immediately following ground-disturbing activities such as excavations, and natural disasters such as range fires, which would reduce or completely remove the ground vegetative cover. Model output for unsaturated flow in unvegetated areas is graphically illustrated in figures 6-7 through 6-11.

6.3.4 Conclusions

Model results indicating a groundwater recharge rate of 1.04 cm/yr (0.41 in/yr) for a vegetated site is comparable to results obtained from actual on-the-ground lysimeter studies conducted elsewhere on the Hanford Site (see paragraph 2.4.3.1). The recharge rate of 3.46 cm/yr (1.36 in/yr) is within the published range for recharge below an unvegetated area recorded during lysimeter studies on the Hanford Site; although on the dry end of most reported limits.

Table 6-6 Initial Suction Heads, Plants Modeled

NODE	HEAD (cm)	NODE	HEAD (cm)	NODE	HEAD (cm)
1	131.326	35	176.474	69	147.981
2	124.583	36	178.828	70	127.987
3	118.683	37	183.623	71	112.990
4	113.484	38	191.465	72	102.992
5	108.792	39	205.044	73	95.9926
6	104.515	40	230.942	74	93.9928
7	87.8913	41	254.677	75	91.9930
8	58.0712	42	295.592	76	91.4931
9	46.0729	43	371.113	77	91.2931
10	55.1736	44	403.534	78	91.0931
11	72.8150	45	449.033	79	90.9931
12	99.7704	46	498.778	80	90.8932
13	159.293	47	507.116	81	90.6932
14	172.919	48	515.957	82	90.4933
15	170.134	49	515.860	83	89.9934
16	176.268	50	515.762	84	87.9940
17	180.922	51	515.565	85	85.9945
18	189.025	52	515.369	86	77.9962
19	188.727	53	514.877	87	67.9978
20	184.825	54	512.909	88	52.9991
21	180.273	55	510.942	89	42.9996
22	178.742	56	501.097	90	32.9998
23	177.117	57	491.244	91	23.0000
24	175.840	58	476.448	92	18.0000
25	175.666	59	456.691	93	13.0000
26	175.491	60	436.905	94	5.00000
27	175.414	61	397.251	95	3.00000
28	175.464	62	377.391	96	.999999
29	175.560	63	342.586	97	.500000
30	175.651	64	302.746	98	.300000
31	175.857	65	267.843	99	.099999
32	176.394	66	227.915	100	0.0000
33	176.630	67	197.949		
34	176.090	68	167.971		

Table 6-7 Initial Suction Heads, Plants Not Modeled

NODE	HEAD (cm)	NODE	HEAD (cm)	NODE	HEAD (cm)
1	118.943	35	43.0274	69	145.509
2	113.584	36	42.0997	70	126.314
3	108.787	37	41.2159	71	111.724
4	104.507	38	40.7483	72	101.924
5	100.600	39	40.8108	73	95.0348
6	97.0004	40	42.3209	74	93.0625
7	82.6371	41	44.5799	75	91.0886
8	55.4025	42	50.6674	76	90.5949
9	44.0472	43	68.4945	77	90.3973
10	48.5146	44	81.1530	78	90.1998
11	57.6727	45	109.521	79	90.1016
12	63.4112	46	183.126	80	90.0054
13	75.7525	47	231.953	81	89.8129
14	88.4700	48	365.349	82	89.6203
15	88.8131	49	365.411	83	89.1387
16	82.0681	50	365.392	84	87.2095
17	77.8838	51	365.355	85	85.2762
18	67.5820	52	365.317	86	77.5017
19	61.5698	53	365.223	87	67.7064
20	54.7590	54	364.840	88	52.8825
21	49.5207	55	364.449	89	42.9469
22	47.9576	56	362.327	90	32.9801
23	46.3623	57	360.094	91	22.9936
24	45.1452	58	356.288	92	17.9967
25	44.9816	59	350.478	93	12.9981
26	44.8177	60	343.825	94	4.99937
27	44.7478	61	327.739	95	2.99962
28	44.7389	62	318.401	96	.999875
29	44.7213	63	299.685	97	.499937
30	44.7037	64	274.599	98	.299962
31	44.6599	65	249.563	99	.099988
32	44.4870	66	217.566	100	0.0000
33	44.3178	67	191.644		
34	43.7553	68	164.314		

Table 6-8: UNSAT-H Model Output (1 of 2)
Plant Option: ON

Year	Yearly Precipitation	Yearly Precipitation (inches)	Actual Transpiration	Actual Evaporation	Total Base Drainage	Final Moisture Storage	Mass Balance Error (%)
1	1.7000E+01	6.69	5.5034E+00	1.0894E+01	1.7133E-02	7.8551E+01	2.6424E-01
2	2.1206E+01	8.35	5.2294E+00	1.2227E+01	1.7134E-02	8.2212E+01	3.4341E-01
3	2.2751E+01	8.96	6.3698E+00	1.4701E+01	1.7135E-02	8.3806E+01	3.0005E-01
4	1.5850E+01	6.24	5.9101E+00	1.0293E+01	1.7135E-02	8.3375E+01	3.7879E-01
5	2.3231E+01	9.15	6.2967E+00	1.3954E+01	1.7182E-02	8.6291E+01	1.9821E-01
6	2.2278E+01	8.77	5.6090E+00	1.4077E+01	3.0914E-02	8.8784E+01	3.0930E-01
7	1.8085E+01	7.12	6.2240E+00	1.0394E+01	3.2955E-01	8.9842E+01	4.3641E-01
8	2.2027E+01	8.67	6.7875E+00	1.4322E+01	2.3259E+00	8.8358E+01	3.4296E-01
9	2.0432E+01	8.04	6.8586E+00	1.3619E+01	1.8671E+00	8.6358E+01	4.2318E-01
10	1.8479E+01	7.27	6.0740E+00	9.8763E+00	1.2894E+00	8.7561E+01	1.9328E-01
11	1.5789E+01	6.22	6.3602E+00	9.4854E+00	1.0013E+00	8.6439E+01	4.0607E-01
12	2.1814E+01	8.59	6.7858E+00	1.4282E+01	1.1447E+00	8.5966E+01	3.4261E-01
13	1.7424E+01	6.86	5.9963E+00	1.1588E+01	1.2008E+00	8.4528E+01	4.3953E-01
14	2.0960E+01	8.25	6.2020E+00	1.2776E+01	9.4858E-01	8.5487E+01	3.5723E-01
15	1.9538E+01	7.69	5.7601E+00	1.2180E+01	7.0901E-01	8.6317E+01	2.9977E-01
16	2.0188E+01	7.95	6.2563E+00	1.2591E+01	5.6848E-01	8.7032E+01	2.8546E-01
17	1.6769E+01	6.60	5.7681E+00	1.1306E+01	7.5907E-01	8.5904E+01	3.7672E-01
18	2.2888E+01	9.01	5.9465E+00	1.3461E+01	1.2282E+00	8.8070E+01	3.7868E-01
19	1.6815E+01	6.62	6.0374E+00	1.2709E+01	9.8328E-01	8.5081E+01	4.3764E-01
20	2.4140E+01	9.50	6.3302E+00	1.4229E+01	7.5047E-01	8.7867E+01	1.8527E-01
21	2.4796E+01	9.76	5.7994E+00	1.4092E+01	9.8082E-01	9.1749E+01	1.6509E-01
22	2.4323E+01	9.58	6.4987E+00	1.6034E+01	2.6833E+00	9.0775E+01	3.3409E-01
23	1.4740E+01	5.80	6.0042E+00	9.5139E+00	2.0995E+00	8.7840E+01	3.8657E-01
24	1.7193E+01	6.77	6.1821E+00	1.1288E+01	1.8132E+00	8.5690E+01	3.4651E-01
25	1.6893E+01	6.65	6.3317E+00	1.0617E+01	1.4011E+00	8.4154E+01	4.7314E-01
26	1.2814E+01	5.04	5.4150E+00	9.4406E+00	9.0448E-01	8.1145E+01	4.9566E-01
27	2.1278E+01	8.38	6.5871E+00	1.2432E+01	6.1420E-01	8.2796E+01	-3.5507E-02
28	1.5974E+01	6.29	5.5811E+00	8.1086E+00	4.4761E-01	8.4569E+01	3.9869E-01
29	2.3526E+01	9.26	6.2115E+00	1.3756E+01	3.4383E-01	8.7715E+01	2.9085E-01
30	1.7729E+01	6.98	5.8741E+00	1.1468E+01	2.7716E-01	8.7752E+01	4.0989E-01
31	1.4135E+01	5.56	5.3537E+00	9.4520E+00	8.8514E-01	8.6139E+01	4.0433E-01
32	1.8849E+01	7.42	6.1167E+00	1.0461E+01	1.5647E+00	8.6764E+01	4.3578E-01
33	2.4638E+01	9.70	6.3686E+00	1.5482E+01	1.2143E+00	8.8261E+01	3.0550E-01
34	1.5362E+01	6.05	6.0011E+00	1.1822E+01	8.5392E-01	8.4876E+01	4.5685E-01
35	1.5321E+01	6.03	5.4946E+00	9.3426E+00	7.9986E-01	8.4488E+01	4.6815E-01
36	3.7115E+01	14.61	6.4731E+00	1.5101E+01	2.2893E+00	9.8519E+01	-2.3919E+00
37	1.8740E+01	7.38	6.0179E+00	1.3422E+01	7.5592E+00	9.0193E+01	3.5204E-01
38	1.9588E+01	7.71	6.0527E+00	1.1159E+01	3.6490E+00	8.8841E+01	4.1079E-01
39	2.4199E+01	9.53	6.6423E+00	1.4088E+01	1.7811E+00	9.0484E+01	1.8401E-01
40	1.7219E+01	6.78	6.6067E+00	1.2386E+01	1.0645E+00	8.7571E+01	4.2929E-01
41	2.2832E+01	8.99	6.4998E+00	1.5704E+01	2.0124E+00	8.6096E+01	3.9544E-01
42	2.1102E+01	8.31	6.4595E+00	1.1834E+01	1.6392E+00	8.7187E+01	3.7261E-01
43	1.2314E+01	4.85	4.9165E+00	8.3683E+00	1.0113E+00	8.5162E+01	3.5159E-01
44	1.8852E+01	7.42	5.9074E+00	1.2435E+01	7.2821E-01	8.4881E+01	3.3174E-01
45	1.8735E+01	7.38	6.7438E+00	1.2525E+01	7.1631E-01	8.3556E+01	3.9649E-01
46	1.4958E+01	5.89	5.5111E+00	9.3724E+00	6.7995E-01	8.2876E+01	4.9881E-01
47	1.5082E+01	5.94	6.1161E+00	9.6692E+00	5.5173E-01	8.1549E+01	4.8692E-01
48	1.6871E+01	6.64	5.8231E+00	1.0368E+01	4.4509E-01	8.1703E+01	4.7180E-01
49	2.1808E+01	8.59	5.6192E+00	1.1574E+01	3.6607E-01	8.5894E+01	2.6666E-01
50	1.5570E+01	6.13	6.6800E+00	1.0296E+01	3.0320E-01	8.4119E+01	4.2672E-01
51	1.8339E+01	7.22	6.8106E+00	1.3054E+01	2.5212E-01	8.2266E+01	4.1252E-01

Table 6-8: UNSAT-H Model Output (2 of 2)
Continued

Year	Yearly Precipitation	Yearly Precipitation (inches)	Actual Transpiration	Actual Evaporation	Total Base Drainage	Final Moisture Storage	Mass Balance Error (%)
52	1.2289E+01	4.84	5.4844E+00	7.6426E+00	2.2189E-01	8.1155E+01	3.7897E-01
53	2.2243E+01	6.68	6.6794E+00	1.3723E+01	2.5617E-01	8.2651E+01	3.9514E-01
54	1.9987E+01	7.87	6.2984E+00	1.4445E+01	3.1215E-01	8.1509E+01	3.6924E-01
55	1.5410E+01	6.07	5.1305E+00	9.3250E+00	3.1401E-01	8.2086E+01	4.1060E-01
56	1.9113E+01	7.52	5.7894E+00	1.1733E+01	2.8038E-01	8.3303E+01	4.9278E-01
57	2.1206E+01	8.35	6.6752E+00	1.2838E+01	2.4155E-01	8.4681E+01	3.5016E-01
58	1.8994E+01	7.48	6.0831E+00	1.1996E+01	2.0882E-01	8.5530E+01	-7.5555E-01
59	1.9370E+01	7.63	5.9592E+00	1.1404E+01	1.8401E-01	8.7289E+01	3.3241E-01
60	1.9588E+01	7.71	6.0903E+00	1.1265E+01	4.2682E-01	8.9022E+01	3.7325E-01
61	1.5052E+01	5.93	6.6265E+00	8.4625E+00	3.1197E+00	8.5802E+01	4.1874E-01
62	2.1356E+01	8.41	6.3187E+00	1.4688E+01	1.8587E+00	8.4230E+01	2.9557E-01
63	2.2078E+01	8.69	6.2100E+00	1.2646E+01	1.0366E+00	8.6322E+01	4.1757E-01
64	1.3906E+01	5.47	5.6450E+00	9.3472E+00	6.5556E-01	8.4519E+01	4.4394E-01
65	1.9068E+01	7.51	6.7436E+00	1.2166E+01	4.5904E-01	8.4132E+01	4.4940E-01
66	2.0297E+01	7.99	5.7370E+00	1.2454E+01	4.0939E-01	8.5778E+01	2.5297E-01
67	2.3663E+01	9.32	5.4965E+00	1.5779E+01	4.7852E-01	8.7600E+01	3.6569E-01
68	1.4607E+01	5.75	5.7592E+00	1.0364E+01	4.6068E-01	8.5556E+01	4.5864E-01
69	1.9878E+01	7.83	6.4090E+00	1.2541E+01	5.1946E-01	8.5899E+01	3.2847E-01
70	1.8801E+01	7.40	5.9344E+00	1.1646E+01	9.8392E-01	8.6069E+01	3.5728E-01
71	1.6744E+01	6.59	6.3216E+00	1.0380E+01	9.6472E-01	8.5081E+01	3.8910E-01
72	1.5138E+01	5.96	5.9209E+00	9.4352E+00	7.4325E-01	8.4052E+01	4.4992E-01
73	1.9662E+01	7.74	6.3435E+00	1.2658E+01	5.5659E-01	8.4087E+01	3.4927E-01
74	2.4407E+01	9.61	7.2304E+00	1.6169E+01	4.4845E-01	8.4566E+01	3.2811E-01
75	2.1991E+01	8.66	6.7086E+00	1.3604E+01	3.8900E-01	8.5784E+01	3.2791E-01
76	1.3477E+01	5.31	5.3000E+00	8.5329E+00	3.7167E-01	8.4987E+01	5.1200E-01
77	1.8352E+01	7.22	5.6968E+00	1.1313E+01	3.9909E-01	8.5872E+01	3.1727E-01
78	1.8473E+01	7.27	5.6911E+00	1.1347E+01	4.7868E-01	8.6780E+01	2.6506E-01
79	1.2471E+01	4.91	6.1848E+00	8.7382E+00	7.4234E-01	8.3523E+01	5.0543E-01
80	1.8044E+01	7.10	5.6368E+00	1.1342E+01	1.2573E+00	8.3249E+01	4.4921E-01
81	2.0028E+01	7.88	6.0285E+00	1.2770E+01	9.4937E-01	8.3453E+01	3.8022E-01
82	1.8877E+01	7.43	5.3753E+00	1.1460E+01	6.5030E-01	8.4812E+01	1.7687E-01
83	2.9903E+01	11.77	6.8305E+00	1.8305E+01	4.6225E-01	8.9145E+01	-9.4327E-02
84	1.4752E+01	5.81	5.9794E+00	8.6041E+00	5.8068E-01	8.8683E+01	3.4422E-01
85	2.1852E+01	8.60	6.2025E+00	1.2560E+01	2.9284E+00	8.8769E+01	3.4018E-01
86	2.2281E+01	8.77	5.9794E+00	1.4026E+01	1.7867E+00	8.9195E+01	2.8015E-01
87	2.4958E+01	9.83	6.6254E+00	1.3033E+01	1.2998E+00	9.3100E+01	3.8126E-01
88	1.5839E+01	6.24	5.7930E+00	9.8688E+00	1.6676E+00	9.1560E+01	3.1212E-01
89	2.2753E+01	8.96	6.4463E+00	1.3827E+01	3.1615E+00	9.0807E+01	3.1586E-01
90	1.7132E+01	6.74	6.0190E+00	1.1657E+01	2.6048E+00	8.7587E+01	4.1894E-01
91	2.7470E+01	10.81	6.1225E+00	1.6565E+01	1.7789E+00	9.0528E+01	2.2658E-01
92	1.6345E+01	6.43	6.0340E+00	1.1431E+01	1.3207E+00	8.8042E+01	2.7829E-01
93	2.0953E+01	8.25	6.3784E+00	1.3470E+01	2.3799E+00	8.6681E+01	4.0325E-01
94	1.9312E+01	7.60	5.6214E+00	1.2281E+01	1.7339E+00	8.6291E+01	3.3758E-01
95	1.7757E+01	6.99	6.2728E+00	1.1241E+01	1.0826E+00	8.5398E+01	2.9941E-01
96	1.7003E+01	6.69	6.0085E+00	9.5332E+00	7.7126E-01	8.6019E+01	4.1015E-01
97	1.3492E+01	5.31	5.4126E+00	8.6770E+00	6.9790E-01	8.4659E+01	4.8223E-01
98	1.3284E+01	5.23	5.8866E+00	9.2244E+00	6.5812E-01	8.2103E+01	5.3421E-01
99	2.1052E+01	8.29	5.8881E+00	1.3501E+01	5.5940E-01	8.3125E+01	3.8486E-01
100	2.4343E+01	9.58	6.0759E+00	1.5747E+01	4.7616E-01	8.5102E+01	2.7373E-01
linimum	1.2289E+01	4.84	4.9165E+00	7.6426E+00	1.7133E-02	7.8551E+01	-2.3919E+00
laximum	3.7115E+01	14.61	7.2304E+00	1.8305E+01	7.5592E+00	9.8519E+01	5.3421E-01
verage	1.9236E+01	7.55	6.0809E+00	1.1994E+01	1.0348E+00	8.5996E+01	3.1944E-01
td. Dev.	3.9770E+00	1.56	4.4101E-01	2.1620E+00	1.0109E+00	2.9114E+00	3.1062E-01

NOTE: All units reported in centimeters unless otherwise noted.

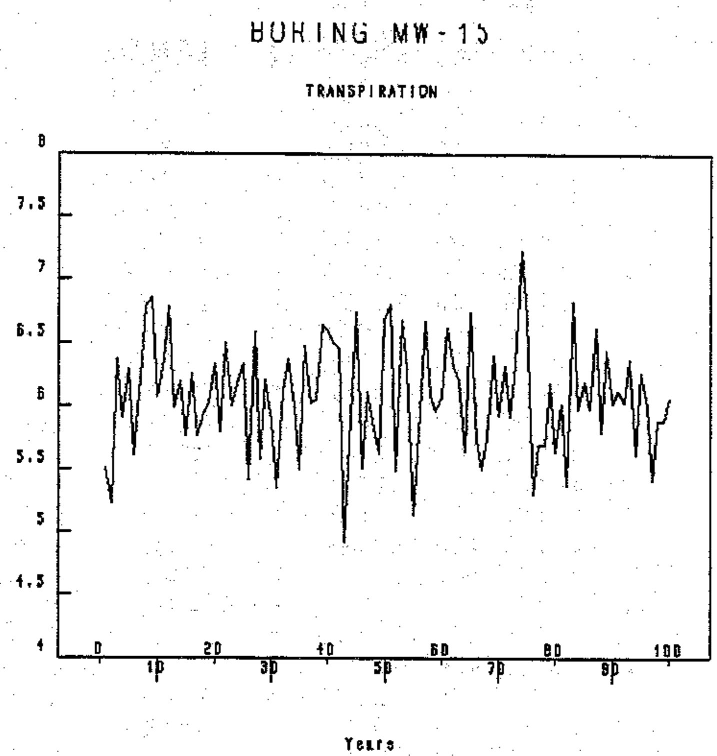

Figure 6-1: Actual Plant Transpiration as Computed by UNSAT-H (cm).

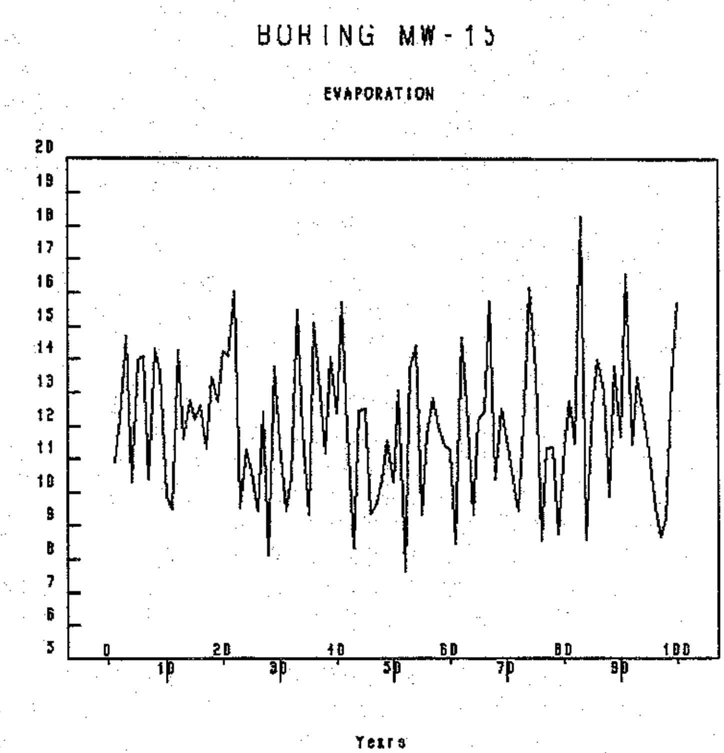

Figure 6-2: Actual Evaporation as Computed by UNSAT-H for a Vegetated Site (cm).

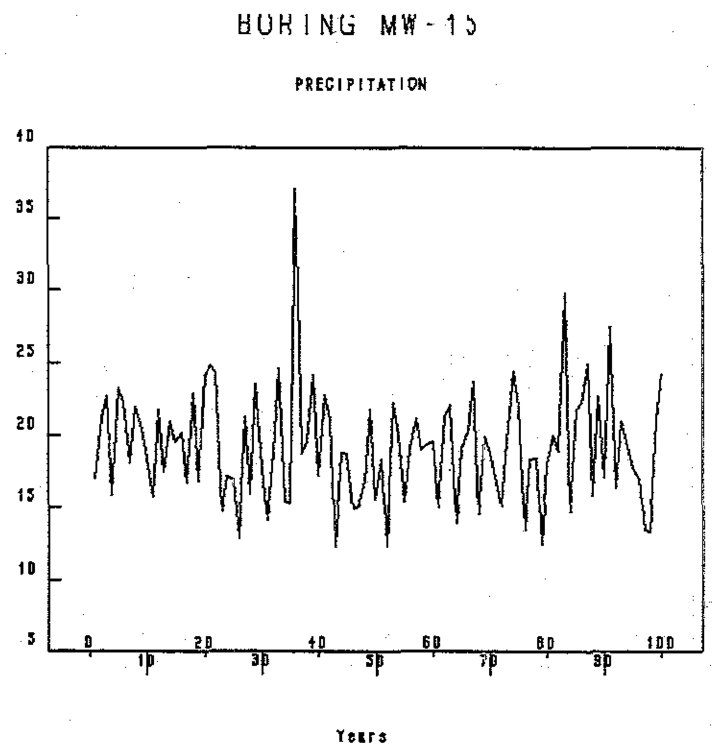

Figure 6-3: Precipitation Values Used in UNSAT-H Simulation (cm).

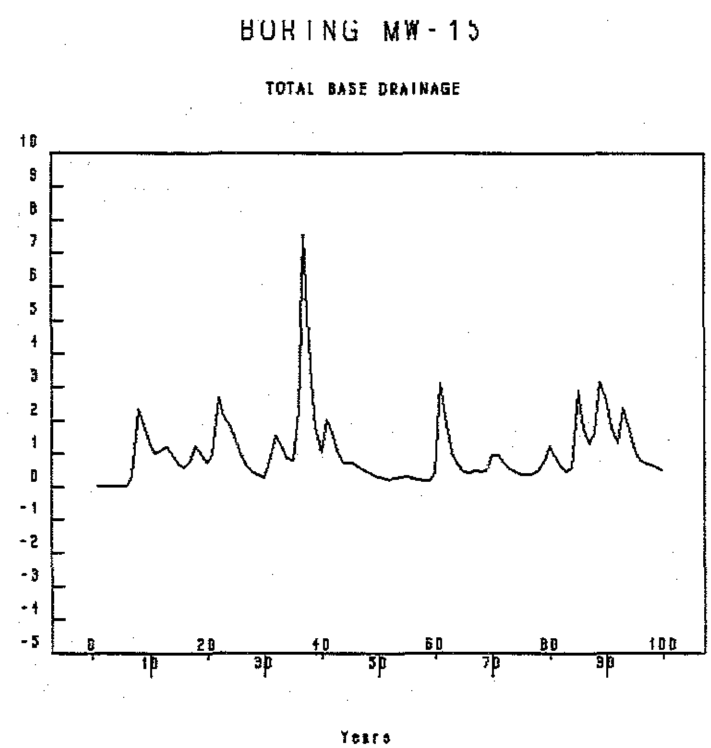

Figure 6-4: Total Soil Column Base Drainage (Recharge) to the Water Table for a Vegetated Site (cm).

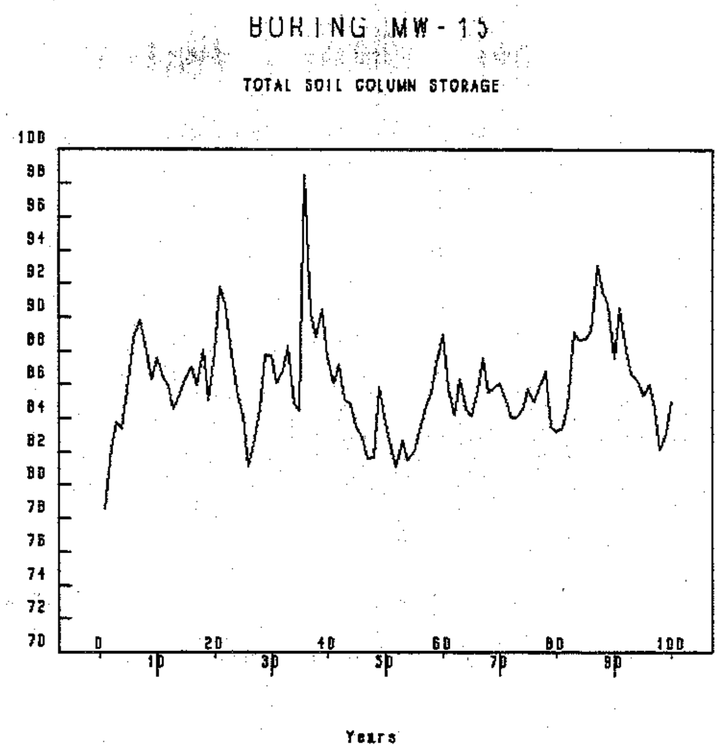

Figure 6-5: Final Yearly Soil Column Moisture Storage as Calculated By UNSAT-H (cm).

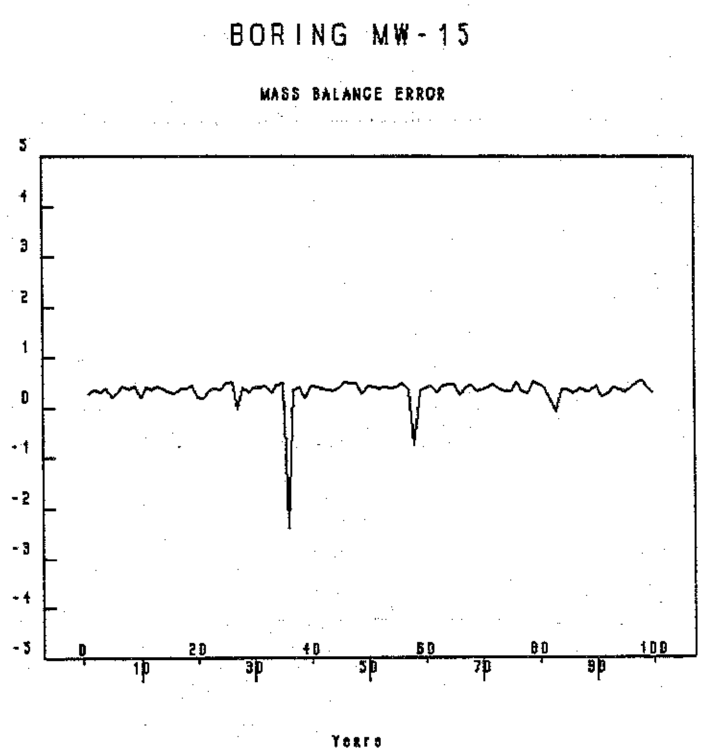

Figure 6-6: UNSAT-H Mass Balance Errors for Each Year of the Simulation (%).

Table 6-9: UNSAT-H Model Output (1 of 2)
Plant Option: OFF

Year	Yearly Precipitation	Yearly Precipitation (inches)	Actual Evaporation	Total Base Drainage	Final Moisture Storage	Mass Balance Error (%)
1	1.7000E+01	6.69	1.4100E+01	2.3140E+00	9.0940E+01	1.6947E-01
2	2.1206E+01	8.35	1.5284E+01	2.3867E+00	9.4427E+01	2.2921E-01
3	2.2751E+01	8.96	1.8455E+01	4.1297E+00	9.4536E+01	2.5305E-01
4	1.5850E+01	6.24	1.3654E+01	4.8522E+00	9.1839E+01	2.5226E-01
5	2.3231E+01	9.15	1.7690E+01	3.5775E+00	9.3777E+01	1.1171E-01
6	2.2278E+01	8.77	1.7293E+01	3.3099E+00	9.5430E+01	9.9536E-02
7	1.8085E+01	7.12	1.3934E+01	5.3738E+00	9.4152E+01	3.0879E-01
8	2.2027E+01	8.67	1.8572E+01	4.9329E+00	9.2604E+01	3.2052E-01
9	2.0432E+01	8.04	1.7916E+01	4.8986E+00	9.1705E+01	3.1460E-01
10	1.8479E+01	7.27	1.9263E+01	3.3537E+00	9.3436E+01	1.2889E-01
11	1.5789E+01	6.22	1.3407E+01	4.1015E+00	9.1675E+01	2.6653E-01
12	2.1814E+01	8.59	1.8624E+01	3.7954E+00	9.1021E+01	2.1611E-01
13	1.7424E+01	6.86	1.5465E+01	2.9600E+00	8.9967E+01	3.0791E-01
14	2.0960E+01	8.25	1.6650E+01	2.2742E+00	9.1948E+01	2.5861E-01
15	1.9538E+01	7.69	1.5532E+01	3.3130E+00	9.2774E+01	2.2525E-01
16	2.0188E+01	7.95	1.6328E+01	3.6498E+00	9.2945E+01	1.9201E-01
17	1.6769E+01	6.60	1.4778E+01	4.3436E+00	9.0544E+01	2.8993E-01
18	2.2888E+01	9.01	1.7086E+01	2.6799E+00	9.3594E+01	3.1260E-01
19	1.6815E+01	6.62	1.6371E+01	2.7545E+00	9.1228E+01	3.2725E-01
20	2.4140E+01	9.50	1.7958E+01	3.8552E+00	9.3526E+01	1.2343E-01
21	2.4796E+01	9.76	1.7493E+01	5.4322E+00	9.5375E+01	8.2499E-02
22	2.4323E+01	9.58	2.0046E+01	4.8815E+00	9.4709E+01	2.5124E-01
23	1.4740E+01	5.80	1.3003E+01	4.2071E+00	9.2201E+01	2.5503E-01
24	1.7193E+01	6.77	1.5106E+01	3.8502E+00	9.0392E+01	2.6986E-01
25	1.6893E+01	6.65	1.4675E+01	2.3214E+00	9.0233E+01	3.2995E-01
26	1.2814E+01	5.04	1.2624E+01	2.0886E+00	8.8291E+01	3.3775E-01
27	2.1278E+01	8.38	1.6603E+01	1.9660E+00	9.1123E+01	-5.7901E-01
28	1.5974E+01	6.29	1.1531E+01	2.6566E+00	9.2865E+01	2.7470E-01
29	2.3526E+01	9.26	1.7383E+01	2.6647E+00	9.6295E+01	2.0359E-01
30	1.7729E+01	6.98	1.4734E+01	5.5404E+00	9.3694E+01	3.1534E-01
31	1.4135E+01	5.56	1.2333E+01	4.8066E+00	9.0648E+01	2.9170E-01
32	1.8849E+01	7.42	1.4412E+01	3.4449E+00	9.1582E+01	3.1082E-01
33	2.4638E+01	9.70	1.9360E+01	2.3256E+00	9.4476E+01	2.3614E-01
34	1.5362E+01	6.05	1.5456E+01	2.1915E+00	8.9244E+01	3.4052E-01
35	1.5321E+01	6.03	1.2749E+01	2.4376E+00	8.9322E+01	3.6857E-01
36	3.7114E+01	14.61	1.8887E+01	6.9744E+00	1.0122E+02	-2.0422E+00
37	1.8740E+01	7.38	1.6926E+01	1.0286E+01	9.2696E+01	2.9620E-01
38	1.9588E+01	7.71	1.9305E+01	4.5449E+00	9.2831E+01	2.7350E-01
39	2.4199E+01	9.53	1.7930E+01	2.5356E+00	9.6550E+01	5.8396E-02
40	1.7219E+01	6.78	1.6411E+01	5.2689E+00	9.2041E+01	2.7770E-01
41	2.2832E+01	8.99	1.9829E+01	4.5821E+00	9.0416E+01	1.9928E-01
42	2.1102E+01	8.31	1.5766E+01	2.6268E+00	9.3069E+01	2.7434E-01
43	1.2314E+01	4.85	1.0926E+01	2.9651E+00	9.1429E+01	2.0911E-01
44	1.8852E+01	7.42	1.6096E+01	3.6108E+00	9.0531E+01	2.2797E-01
45	1.8735E+01	7.38	1.9216E+01	2.3039E+00	9.0196E+01	2.8932E-01
46	1.4958E+01	5.89	1.2667E+01	2.5143E+00	8.9919E+01	3.6098E-01
47	1.5082E+01	5.94	1.3618E+01	2.3864E+00	8.8945E+01	3.4383E-01
48	1.6871E+01	6.64	1.4069E+01	1.9429E+00	8.9746E+01	3.4288E-01
49	2.1808E+01	8.59	1.5014E+01	1.6922E+00	9.4814E+01	1.5607E-01
50	1.5570E+01	6.13	1.4299E+01	2.8331E+00	9.3206E+01	2.9822E-01
51	1.8339E+01	7.22	1.7520E+01	4.3258E+00	8.9643E+01	3.0444E-01

Table 6-9: UNSAT-H Model Output (2 of 2)
Plant Option: OFF

Year	Yearly Precipitation	Yearly Precipitation (inches)	Actual Evaporation	Total Base Drainage	Final Moisture Storage	Mass Balance Error (%)
52	1.2289E+01	4.84	1.0889E+01	2.4969E+00	8.8521E+01	2.0357E-01
53	2.2243E+01	8.76	1.8234E+01	2.1104E+00	9.0358E+01	2.7249E-01
54	1.9987E+01	7.87	1.8471E+01	1.8470E+00	8.9977E+01	2.1110E-01
55	1.5410E+01	6.07	1.2301E+01	2.5034E+00	9.0541E+01	2.7381E-01
56	1.9113E+01	7.52	1.5327E+01	2.1185E+00	9.2137E+01	3.7856E-01
57	2.1206E+01	8.35	1.7083E+01	2.3608E+00	9.3845E+01	2.5353E-01
58	1.8994E+01	7.48	1.5537E+01	3.5684E+00	9.3915E+01	-9.5840E-01
59	1.9370E+01	7.63	1.4891E+01	3.9223E+00	9.4422E+01	2.6092E-01
60	1.9588E+01	7.71	1.4843E+01	6.5323E+00	9.2587E+01	2.4595E-01
61	1.5052E+01	5.93	1.2606E+01	5.1733E+00	8.9818E+01	2.7365E-01
62	2.1356E+01	8.41	1.8961E+01	2.4036E+00	8.9774E+01	1.6390E-01
63	2.2078E+01	8.69	1.6610E+01	1.7326E+00	9.3441E+01	3.0989E-01
64	1.3906E+01	5.47	1.2410E+01	2.5769E+00	9.2307E+01	3.7847E-01
65	1.9068E+01	7.51	1.5567E+01	1.1690E+00	9.0577E+01	3.2304E-01
66	2.0297E+01	7.99	1.5840E+01	2.3270E+00	9.2681E+01	1.2976E-01
67	2.3663E+01	9.32	1.8972E+01	2.2243E+00	9.5091E+01	2.4308E-01
68	1.4607E+01	5.75	1.3822E+01	4.0965E+00	9.1730E+01	3.3993E-01
69	1.9878E+01	7.83	1.6534E+01	4.0409E+00	9.0986E+01	2.3972E-01
70	1.8801E+01	7.40	1.5238E+01	3.0049E+00	9.1504E+01	2.1850E-01
71	1.6744E+01	6.59	1.4294E+01	2.2434E+00	9.1659E+01	3.0267E-01
72	1.5138E+01	5.96	1.9442E+01	2.6776E+00	9.0966E+01	3.3383E-01
73	1.9662E+01	7.74	1.6581E+01	2.4309E+00	9.1572E+01	2.2430E-01
74	2.4407E+01	9.61	2.0744E+01	3.0652E+00	9.2109E+01	2.4809E-01
75	2.1991E+01	8.66	1.7905E+01	2.9000E+00	9.3249E+01	2.1092E-01
76	1.3477E+01	5.31	1.1478E+01	3.5143E+00	9.1675E+01	4.3280E-01
77	1.8352E+01	7.22	1.4701E+01	2.8420E+00	9.2443E+01	2.2331E-01
78	1.8473E+01	7.27	1.4564E+01	3.4882E+00	9.2823E+01	2.2085E-01
79	1.2471E+01	4.91	1.2480E+01	4.4900E+00	8.8278E+01	3.6308E-01
80	1.8044E+01	7.10	1.5188E+01	2.4320E+00	8.8647E+01	3.0652E-01
81	2.0028E+01	7.88	1.6598E+01	1.7471E+00	9.0286E+01	2.2004E-01
82	1.8877E+01	7.43	1.4247E+01	1.7500E+00	9.3148E+01	9.6878E-02
83	2.9903E+01	11.77	2.1856E+01	4.3062E+00	9.7008E+01	-5.7736E-01
84	1.4752E+01	5.81	1.2113E+01	7.3835E+00	9.2234E+01	2.0065E-01
85	2.1852E+01	8.60	1.6514E+01	4.7895E+00	9.2724E+01	2.6415E-01
86	2.2280E+01	8.77	1.7333E+01	3.1070E+00	9.4516E+01	2.1940E-01
87	2.4958E+01	9.83	1.7105E+01	4.3458E+00	9.7954E+01	2.7685E-01
88	1.5839E+01	6.24	1.3184E+01	5.7420E+00	9.4837E+01	1.9279E-01
89	2.2753E+01	8.96	1.7830E+01	5.3473E+00	9.4360E+01	2.3241E-01
90	1.7132E+01	6.74	1.5328E+01	4.4587E+00	9.1658E+01	2.8250E-01
91	2.7470E+01	10.81	2.0270E+01	3.3054E+00	9.5508E+01	1.6170E-01
92	1.6345E+01	6.43	1.4903E+01	4.8473E+00	9.2072E+01	1.8747E-01
93	2.0953E+01	8.25	1.7426E+01	4.6474E+00	9.0891E+01	2.9271E-01
94	1.9312E+01	7.60	1.5662E+01	2.8783E+00	9.1612E+01	2.6001E-01
95	1.7757E+01	6.99	1.5074E+01	2.5934E+00	9.1660E+01	2.3118E-01
96	1.7003E+01	6.69	1.3121E+01	3.5143E+00	9.1972E+01	3.3324E-01
97	1.3492E+01	5.31	1.1658E+01	2.4817E+00	9.1277E+01	3.5020E-01
98	1.3284E+01	5.23	1.2851E+01	2.7938E+00	8.8864E+01	3.9685E-01
99	2.1052E+01	8.29	1.7351E+01	2.3034E+00	9.0202E+01	2.7905E-01
100	2.4343E+01	9.58	1.9383E+01	1.8211E+00	9.3306E+01	1.4874E-01
Minimum	1.2289E+01	4.84	1.0889E+01	1.1690E+00	8.8278E+01	-2.0422E+00
Maximum	3.7114E+01	14.61	2.1856E+01	1.0286E+01	1.0122E+02	4.3280E-01
Average	1.9236E+01	7.57	1.5857E+01	3.4552E+00	9.2235E+01	2.0544E-01
Std. Dev.	3.9770E+00	1.57	2.4336E+00	1.4250E+00	2.1940E+00	2.8994E-01

NOTE: All units reported in centimeters unless otherwi

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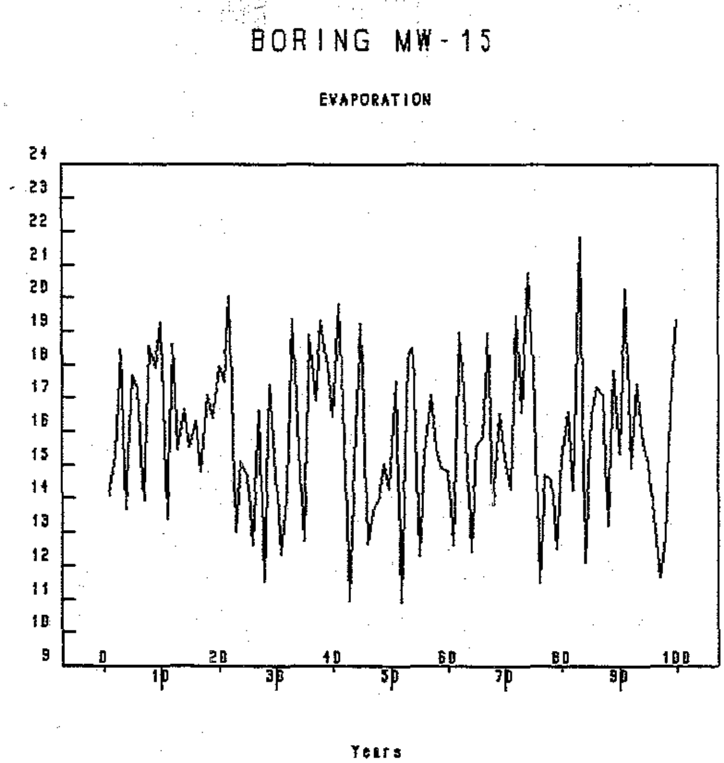


Figure 6-7: Actual Evaporation as Computed by UNSAT-H for an Unvegetated Site (cm).

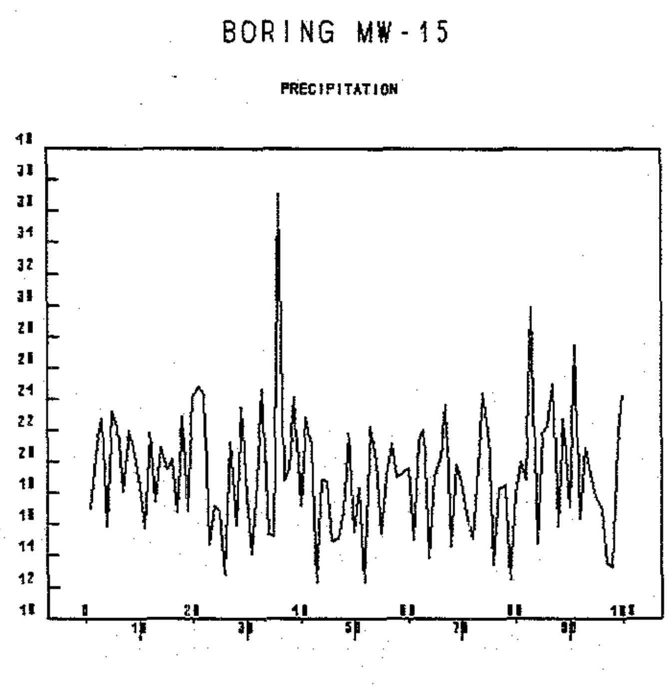


Figure 6-8: Precipitation Values Used in UNSAT-H Simulation (cm).

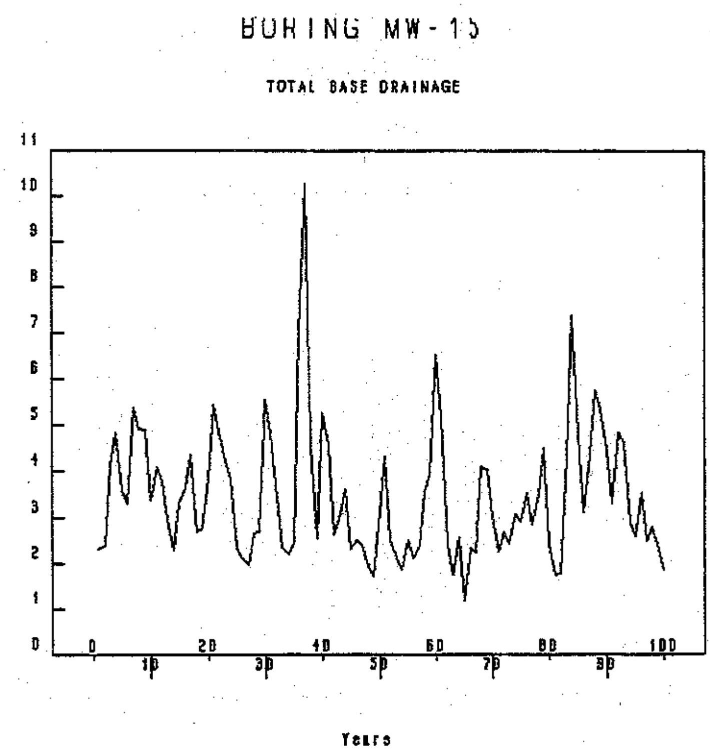


Figure 6-9: Total Soil Column Base Drainage (Recharge) to the Water Table for an Unvegetated Site (cm).

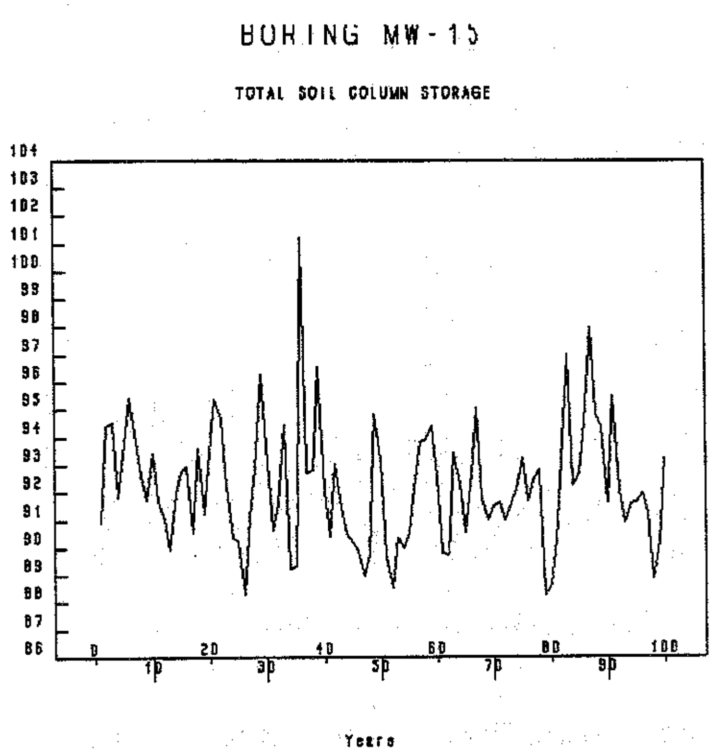


Figure 6-10: Final Soil Column Moisture Storage as Calculated by UNSAT-H for an Unvegetated Site (cm).

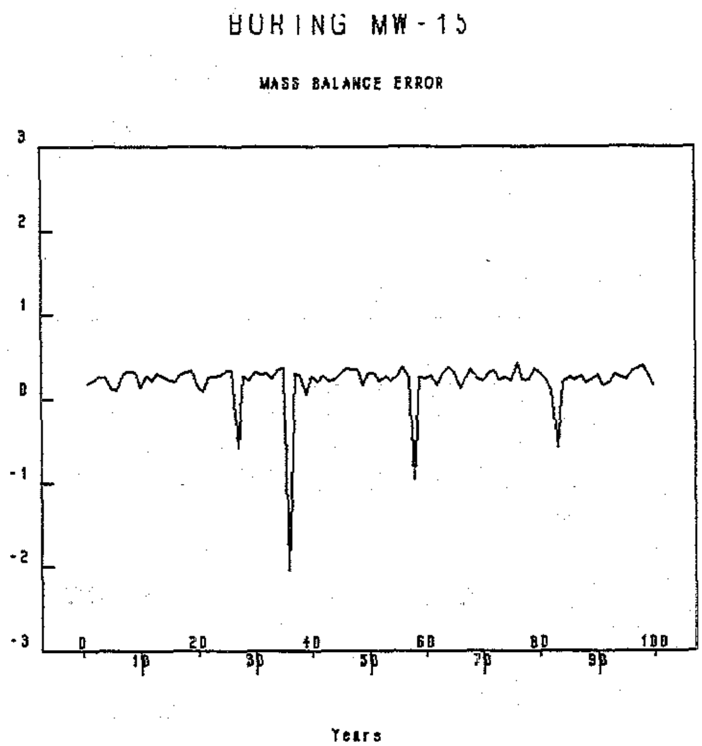


Figure 6-11: UNSAT-H Yearly Simulation Mass Balance Errors (%).

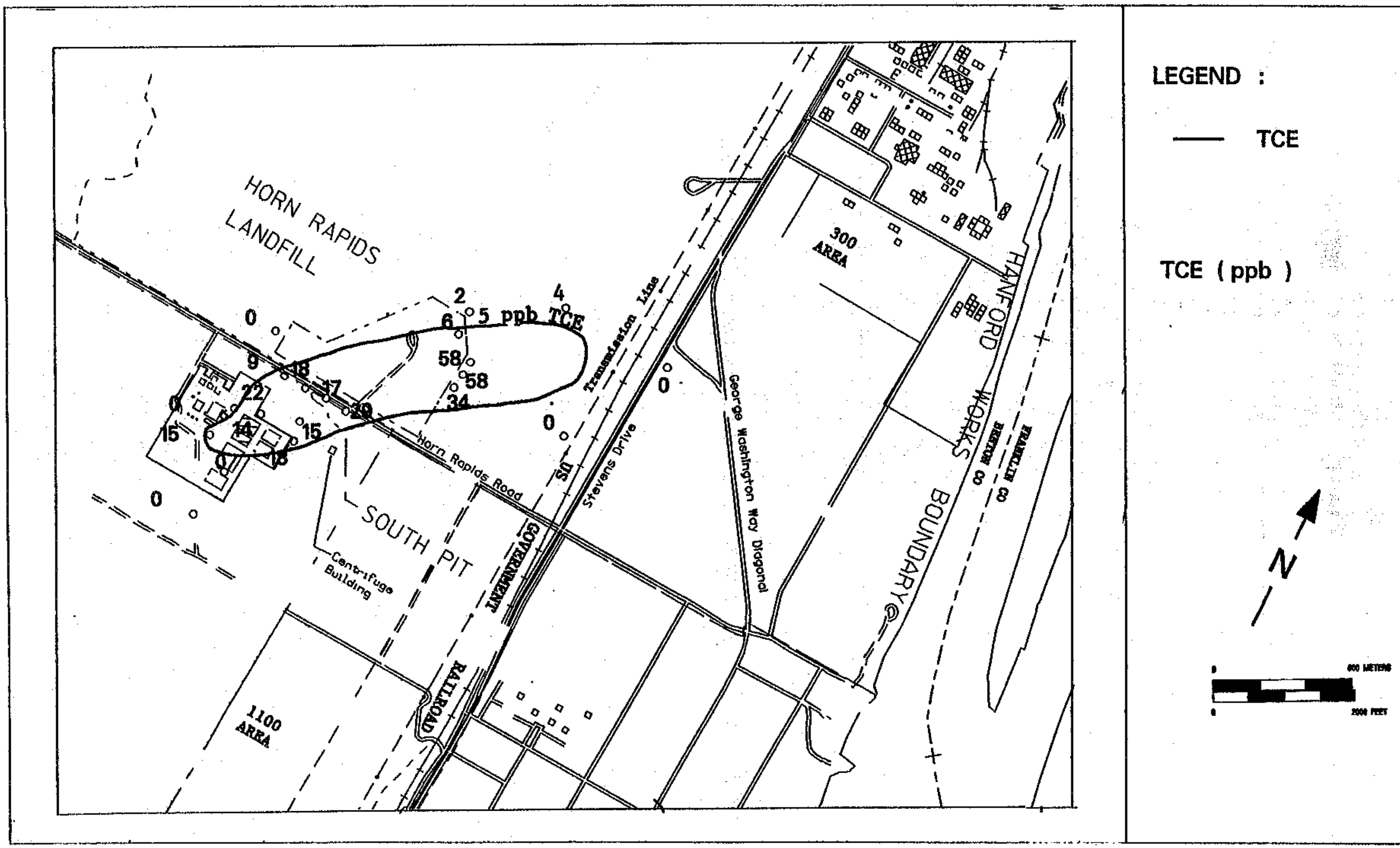


Figure 6-12. TCE Concentration Data and Approximate Plume Extent, March, 1992.

6.4 SATURATED ZONE CONTAMINANT TRANSPORT MODELING

The purpose of modeling the groundwater flow and contaminant transport at the 1100-EM-1 Operable Unit was to determine the migration rate and persistence of the contaminants of concern for the baseline condition (*i.e.*, no active remediation) and to evaluate the effectiveness of selected groundwater remediation alternatives. The primary contaminant of concern was TCE. Figure 6-12 shows the observed TCE concentration levels and approximate plume delineation for March, 1992. The modeling analysis provided predicted migration and attenuation rates for the baseline (natural) condition and selected extraction-treatment-infiltration (pump and treat) remediation scenarios. The modeling analysis also provided a better understanding of the origin of the TCE contaminant.

6.4.1 Conceptual Model

Groundwater flow and contaminant transport at the site were simulated for the area shown in figure 6-13. The model area boundaries were oriented to minimize hydraulic flux across the northern and southern boundaries and to avoid the possibility of computed contaminant plumes approaching the edges of the model grid. Prevailing groundwater flow enters the model area from the southwest and travels northeastward toward the Columbia River. The North Richland well field and recharge area and the active agricultural area west of the SPC facility are not within the model boundaries although effects of these features were included in model boundary conditions. As discussed in section 2.4.3, the North Richland well field operation has not had, and is not likely to have, an effect on contaminant plume movement at the SPC/HRL area. In the unlikely event that seasonal recharge mounding does extend to the plume area in the future, its effect would be to temporarily redirect the groundwater flow gradient further northward from its current northeast direction. The resulting effects from this would likely increase contaminant travel times to down-gradient locations, such as the Columbia River, and increase contaminant dispersion by spreading the plume.

Observed groundwater levels in wells immediately adjacent to the river indicate vertical water table fluctuations of about 2.0 m (6.6 ft), which directly correlate to river stage fluctuations. Near the up-gradient (western) boundary of the study area, data from well MW-8 show water table fluctuations of about 0.3 m (1 ft) caused mainly by seasonal increases in up-gradient recharge. Numerical simulations included these fluctuations by calibrating the model to three different observed water table data sets representing the high, average, and low water table conditions.

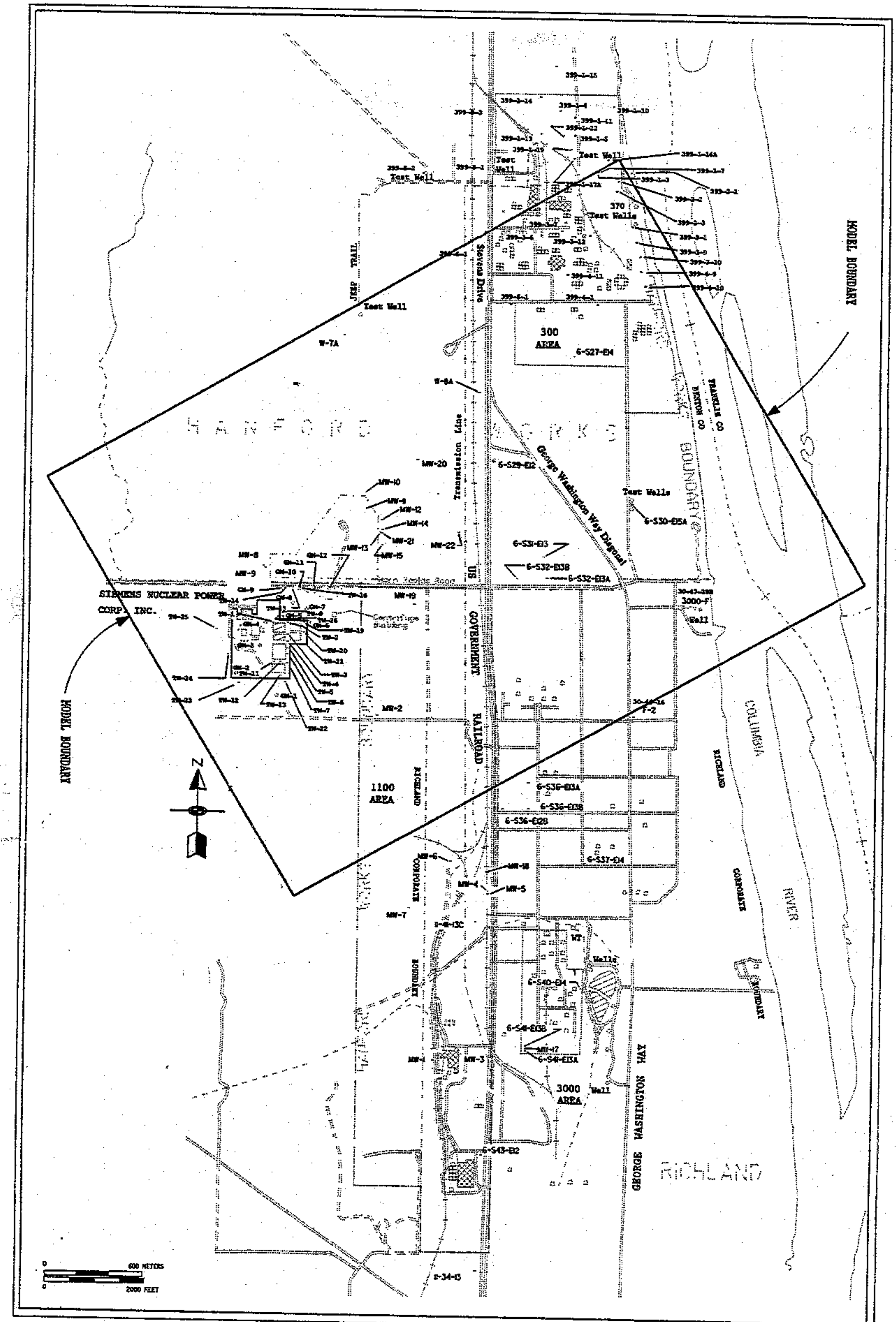
The unconfined aquifer (upper aquifer), upper aquitard, and underlying confined to semi-confined aquifer (lower aquifer) form the model hydrogeologic units. The model included the units underlying the silt aquitard to more accurately represent site flow, however, finer definition was emphasized for the unconfined aquifer because the contaminants of concern have only been detected there. The Hanford and Ringold Formation soils in the unconfined aquifer exhibit different hydraulic properties; the estimated horizontal hydraulic conductivities being 400 to 520 m/d (1,320 to 1,700 ft/d) and 10 to 72 m/d (33 to 236 ft/d), respectively (discussion in section 2.0). These units were differentiated in the model. Average Darcy velocity estimates for flow in the unconfined aquifer were estimated to be 0.1 to 0.3 m/d (0.3 to 1.0 ft/d) (Ringold Formation) and 0.4 to 1.0 m/d (1.3 to 3.3 ft/d) (Hanford formation). These estimates were based on reported hydraulic conductivities (see table 2-7) and the average pressure gradients (see figure 6-19). The site geology and hydrogeology are discussed in section 2.

Positive pressure head differences, occurring between the confined and unconfined aquifers, were observed at the western boundary of the HRL, just west of Stevens Drive, and near the Columbia River.These observations indicated upward pressure head differences of 2.0 m (6.6 ft) up-gradient of HRL, 0.3 m (1.0 ft) near Stevens Drive, and less than 0.1 m (0.3 ft) near the river. This data is consistent with the observation of the upper silt layer becoming discontinuous and/or nonexistent in parts of the eastern portion of the modeled area, adjacent to the river.

Groundwater flow into the modeled area included recharge from precipitation through the upper surface, upward seepage through the lower surface, and some horizontal flux inward through all horizontal boundaries except the river boundary, which had outward flux. The main source of horizontal flow for the unconfined aquifer is the Yakima River located nearly 3.2 km (2 mi) west of the area.

The analysis included contaminant transport of the TCE plume extending from the SPC plant area northeastward toward the Columbia River. Only limited analysis of the nitrate plume was accomplished. As described in section 4.7.2.3, the extent of the nitrate plume could not be completely defined. The nitrate source term was more uncertain than the TCE source term. More appropriately, a thorough modeling of the nitrate plume was not considered essential for analysis of remediation alternatives.

Migration of TCE can include processes of advection, retardation due to adsorption, dispersion, degradation, and volatilization. These processes were listed in their approximate order of influence on TCE migration rates for the site. Advective transport is proportional to the effective groundwater velocities, which are dependent on the hydraulic conductivity and porosity of the host material and the aquifer pressure gradient. Advective transport is, therefore, the most accurately defined of the transport processes because of the available hydraulic conductivity and water level observations at the site. Retardation due to the adsorption-desorption relationship between TCE and the host material is known to occur at the site. The details defining the exact relationship on the micro-scale were not available, and may not be useful, because of potential scale effects encountered when applying small scale measurements to a large scale analysis. Similar difficulties exist for determining dispersion, degradation, and volatilization effects on an aquifer-wide scale. The approach used in this analysis, as discussed further in the model calibration sections (paragraphs 6.4.5.1 and 6.4.5.2), was to determine estimates of the factors governing these processes from the observed history of the plume itself. In other words, the observed nature and



1100-EM-1 Groundwater Model Boundaries and Well Locations.

Figure 6-13

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extent of the plume, through time, was the best available indicator of the effects of retardation and dispersion processes. The effects of biodegradation and volatilization of TCE were not modeled, thus making the model results conservative (*i.e.*, the computed persistence of the TCE was overestimated because the actual losses due to biodegradation and volatilization were not included). Refer to chapter 5 of the Phase I RI report for a more complete discussion on basic subsurface transport.

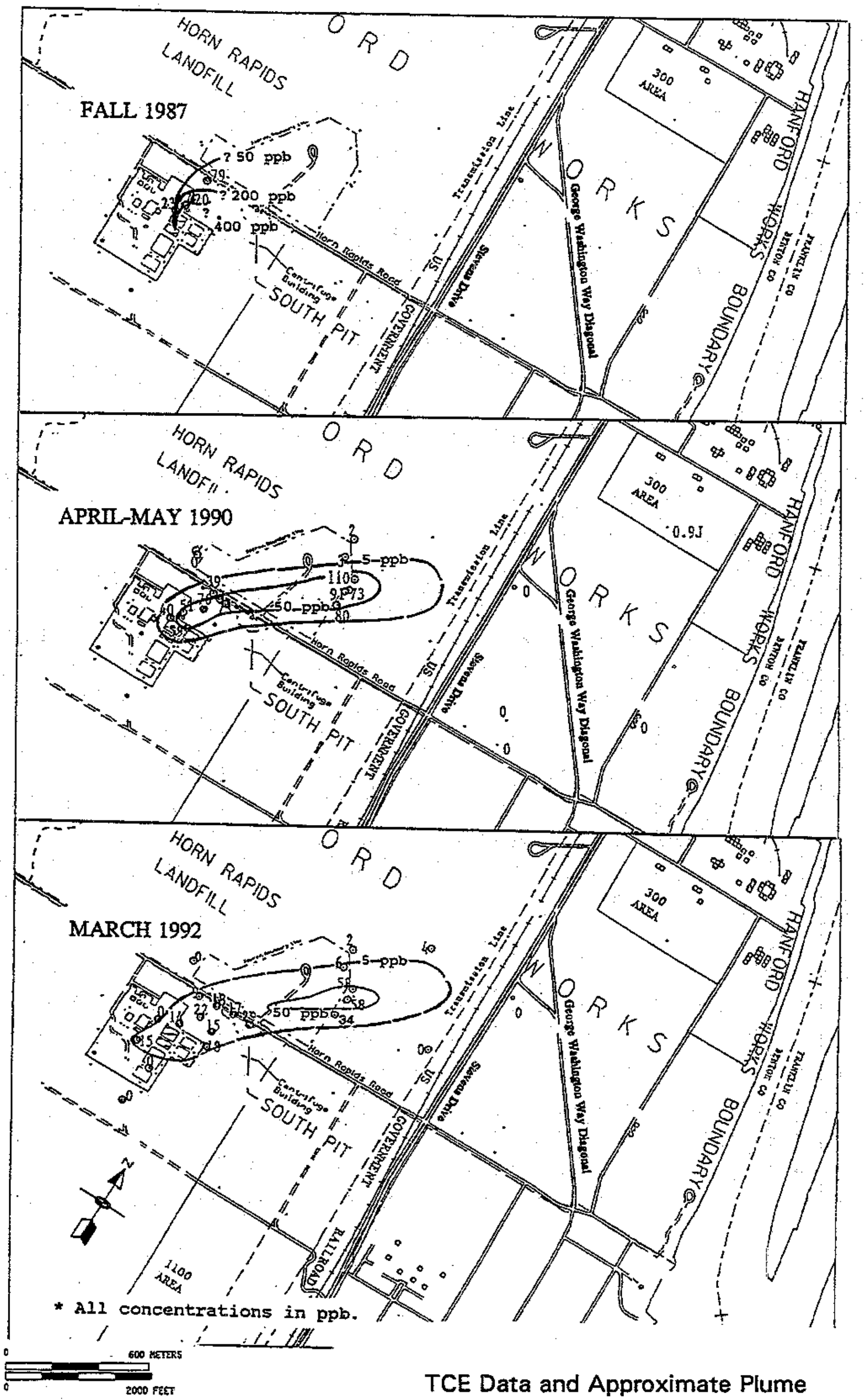
The available TCE data for the earliest (fall, 1987), latest (March, 1992), and one intermediate (April through May, 1990) sampling rounds, determined the approximate extent of the plume through time as shown in figure 6-14. Data indicates that in the 5-year period from 1987 to 1992, natural attenuation caused the maximum TCE concentration to reduce from 420 to 58 ppb. Nitrate levels have also attenuated from about 1,000 to 2,000 ppm (exact value is not known because only total nitrogen was measured) in 1977 at TW-2, to a maximum value of 52 ppm in 1992. These reductions indicate that the site hydrogeology allows for significant decrease in contaminant levels due to natural attenuation, which is, in turn, due to dispersion and the other processes discussed above. Section 4.0 provided additional contaminant characterization and plume description.

6.4.2 Comparison With The Phase I RI Model Analysis

During the Phase I RI, a PORFLOW™ model was constructed for the purpose of estimating contaminant migration at the site. This model was two-dimensional, homogeneous, and used assumed ranges of hydraulic and contaminant transport parameters. Results from this model provided rough, widely-banded estimates of TCE and nitrate plume migration but lacked the detail and capability to provide calibrated simulations of plume migration and remedial action scenarios. Subsequent to the Phase I RI, additional information on hydraulic parameters, site stratigraphy, and contaminant source data was gathered and a three-dimensional, heterogeneous model was constructed and calibrated to include variable river stages, recharge, vertical seepage, horizontal boundary flux, and more detailed hydraulic and contaminant transport parameters. Table 6-10 summarizes the differences between the Phase I RI model and this final RI/FS report model.

6.4.3 Numerical Model Description

Groundwater flow and contaminant transport were simulated numerically through use of PORFLOW™, a finite-difference software package developed by Analytical & Computational Research, Inc. (ACRI), Los Angeles, California. Version 2.40.1 was used, which, for the scope used in this is modeling study (*i.e.*, single phase, saturated flow), is computationally equivalent to earlier PORFLOW™ versions. Descriptions of PORFLOW™ capabilities, and reasons that it is included in the list of Hanford Site software, are found in DOE/RL-91-44. The PORFLOW™-based simulations were run on a DELL® 486 personal



TCE Data and Approximate Plume Delineations.

Figure 6-14

9 3 1 2 9 3 3 0 3 2 8

computer at the offices of the U.S. Army Corps of Engineers, Walla Walla District. Successful software installation was verified by comparing test file output provided by ACRI with test file output from runs made by the U.S. Army Corps of Engineers on April 14, 1992. No significant numerical differences were observed.

The modeling analysis was accomplished in a manner that emphasized accuracy of groundwater flow velocities and contaminant transport in the areas of SPC and HRL and down-gradient to the Columbia River. Refinement of other model aspects, such as total water budget, seepage from the basalt aquifer, 300 Area groundwater contamination, *etc.*, were not emphasized as data defining them was not available, and their significance to the simulation of the 1100 Area contaminant plume was minimal.

6.4.3.1 Model Grid Definition and Hydrofacie Zones. Figure 6-15 shows the horizontal grid definition and boundaries of the model. For numerical modeling purposes, the model area was divided into a 65 by 42 grid mesh with variable horizontal node spacing ranging from 30.5 by 30.5 to 122.0 by 305.0 m (100.1 by 100.1 by 400.3 ft by 1000.7 ft). The longer axis of the modeled area is 3,965 m long (about 2.5 mi), the shorter axis is 2,928 m (about 1.8 mi), with a total area of 11.6 km^2 (about 4.5 mi^2). Vertical model definition was accomplished using 15 layers, ranging in thickness from 1 to 33.5 m (3.3 to 109.9 ft) thick as shown in figure 6-16. The largest xy, xz, and yz aspect ratios were located near the grid boundary and were 1/10, 1/183, and 1/305 respectively. Differentiation between the distinct hydrogeological units (hydrofacies) was accomplished by dividing the three dimensional grid into zones that follow the prevailing site hydrogeologic boundaries. Figure 6-17 shows the hydrofacies zone designation for layer 12 and shows the delineation of the zones representing the Ringold Formation above the silt (Zone 4), the Hanford formation near HRL (Zone 8), and other zones for this model layer. The properties associated with each zone are listed in table 6-15. Figures H-1 through H-15 in appendix H show the zone definition of all 15 grid layers. This discretized zone placement was developed from the isopach and formation contact maps provided in appendix C. These maps were based on drill logs and other data collected during well development.

6.4.3.2 Boundary Conditions. The model boundary conditions are listed in table 6-11. The western boundary (up-gradient boundary) was represented by constant head nodes ranging in elevation from 108.7 to 109.2 m (356.6 to 358.3 ft) for the unconfined upper layers, and 110.7 m (363.2 ft) for the lower layers (below the silt aquitard). These values were taken from up-gradient extrapolation of observations in wells in the HRL/SPC area. This extrapolation was not intended to predict groundwater elevations at the boundary, but was done to provide a starting point for the model to match the observed levels in the area of interest (*i.e.*, from the SPC area down-gradient toward the Columbia River).

Table 6-10 Comparison of Remedial Investigation and Feasibility Study Groundwater Models

Remedial Investigation	Feasibility Study
Used PORFLOW, v-1.0	Used PORFLOW, v-2.40.1
2-dimensional	3-dimensional
Constant grid with 61.0x61.0 meter node spacing	Variable grid with closest node spacing of 30.5x30.5 meters
Constant assumed boundaries	Constant boundaries with variable boundary check
Uncalibrated model	Calibrated model
Homogeneous soil	Heterogeneous soil
No recharge or seepage	Recharge and seepage
Assumed source range at HRL	Improved correlation to TCE use

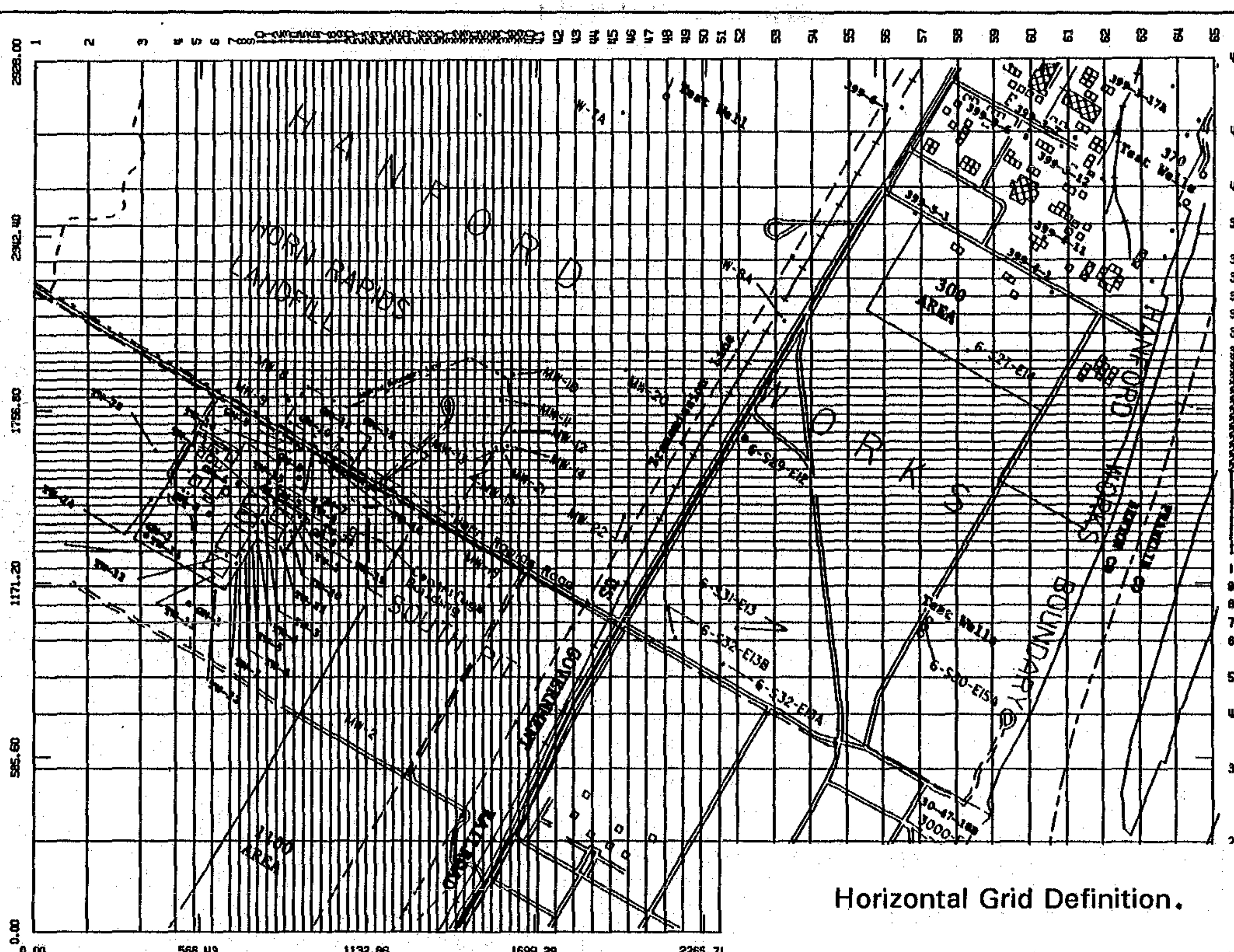
The eastern boundary (river boundary) was modeled with constant head nodes set at the appropriate levels for the high, average, and low river stage conditions. The nodes representing the unconfined layers varied from elevations 105.30 m to 105.65 m (high) (345.49 to 346.64 ft), 104.35 m to 104.70 m (average) (342.37 to 343.52 ft), and 103.65 m to 104.00 m (low) (340.08 to 341.22 ft). These values correspond to the observed water levels in wells near the river for the June 1990, February through March, 1990, and September, 1990, groundwater level data sets shown in figures 6-18 through 6-20. A statistical analysis of the water levels in wells near the river showed that the water elevations in the above three periods were higher than 97 percent, 48 percent, and 7 percent of observed levels from January, 1990, to January, 1992. These three periods were used as the high, average, and low water table conditions. Lower layers had constant nodes set 0.1 m (0.3 ft) higher than upper layer nodes as determined by observations in wells 399-1-16a and -b, and 399-1-17a and -b.

The northern boundary was set as a no-flow boundary except near the northeast corner where constant head elevations were set according to the river stage. The point where the boundary condition changed from no-flow to constant head ranged from grid column 56 to 59 for the three river-boundary conditions.

The southern boundary was initially set as a no-flow boundary but positive inward fluxes were added as determined in the calibration process as discussed in the calibration section (paragraph 6.4.5.1)

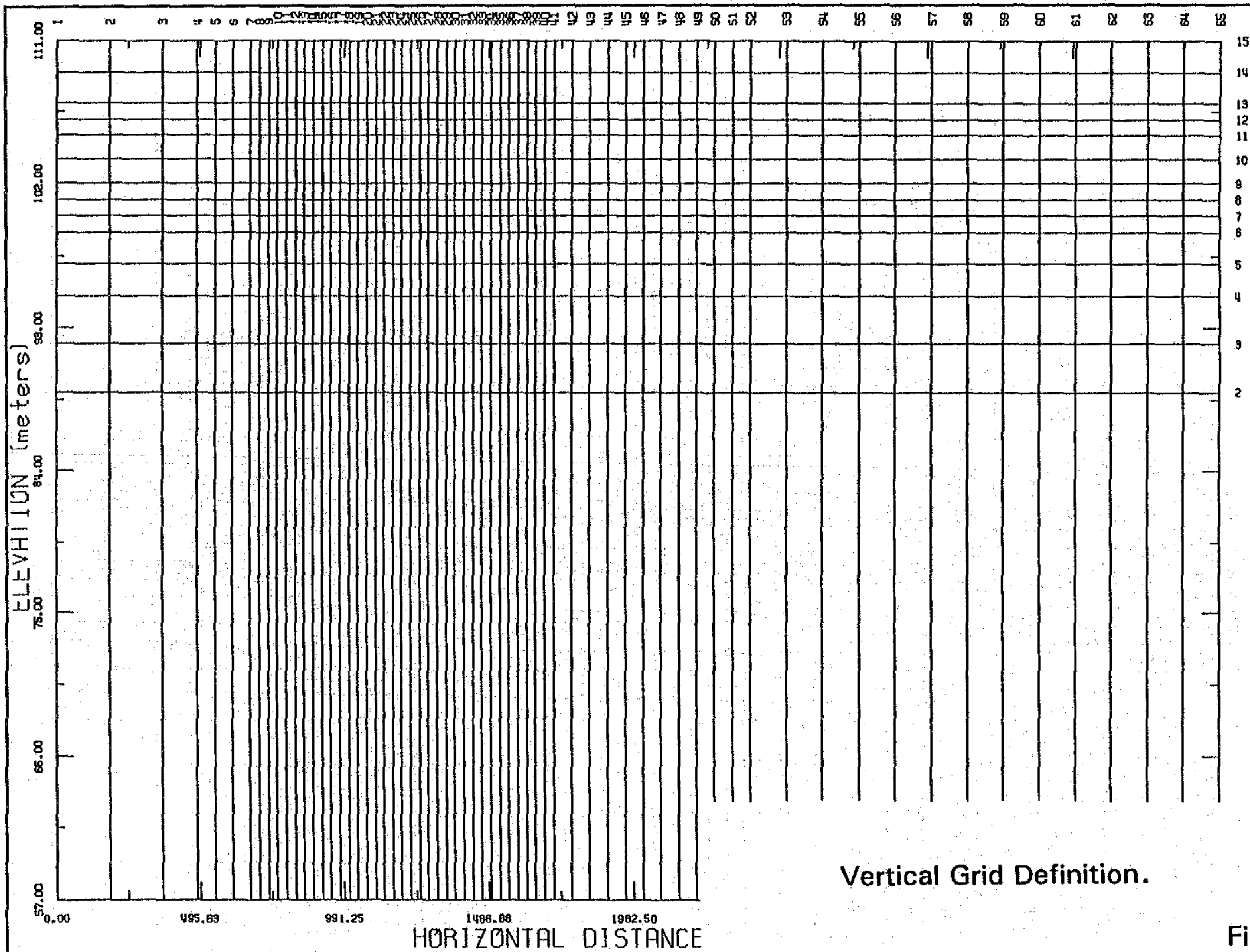
The upper model surface boundary was set as a uniform constant downward flux (vertical recharge) of 1.0E-5 m/d (0.13 inches/year). This value was determined from initial vadose zone modeling runs (see sensitivity and calibration sections for further discussion on the relative importance of recharge). The PORFLOW™ software was not capable of treating this boundary as a free surface boundary but computed the entire 3-dimensional grid as saturated flow. Although the upper surface was chosen at an elevation near the actual water table, the area of the model near the river had higher than actual transmissivities because the groundwater surface slopes downward at this location. This was not a large concern for the analysis because the model was calibrated so that total pressure heads and hydraulic conductivities (and, as a result, computed groundwater velocities, the important factor in determining contaminant migration) matched the observed data. In other words, the model appropriately matched the groundwater velocities and, because of the software constraints, no attempt was made to match the total water budget. This approach is consistent with the stated model objectives.

The lower model surface was set with a uniform constant upward flux of 5.0E-4 m/d (16.4E-4 ft/d). This value was determined in the calibration process and corresponds to values of 10 m (32.8 ft) of positive head differential across a 10-m thick lower silt aquitard (an observed value) and a vertical hydraulic conductivity value of about 5.0E-4 m/d (16.4E-4 ft/d) for that unit.



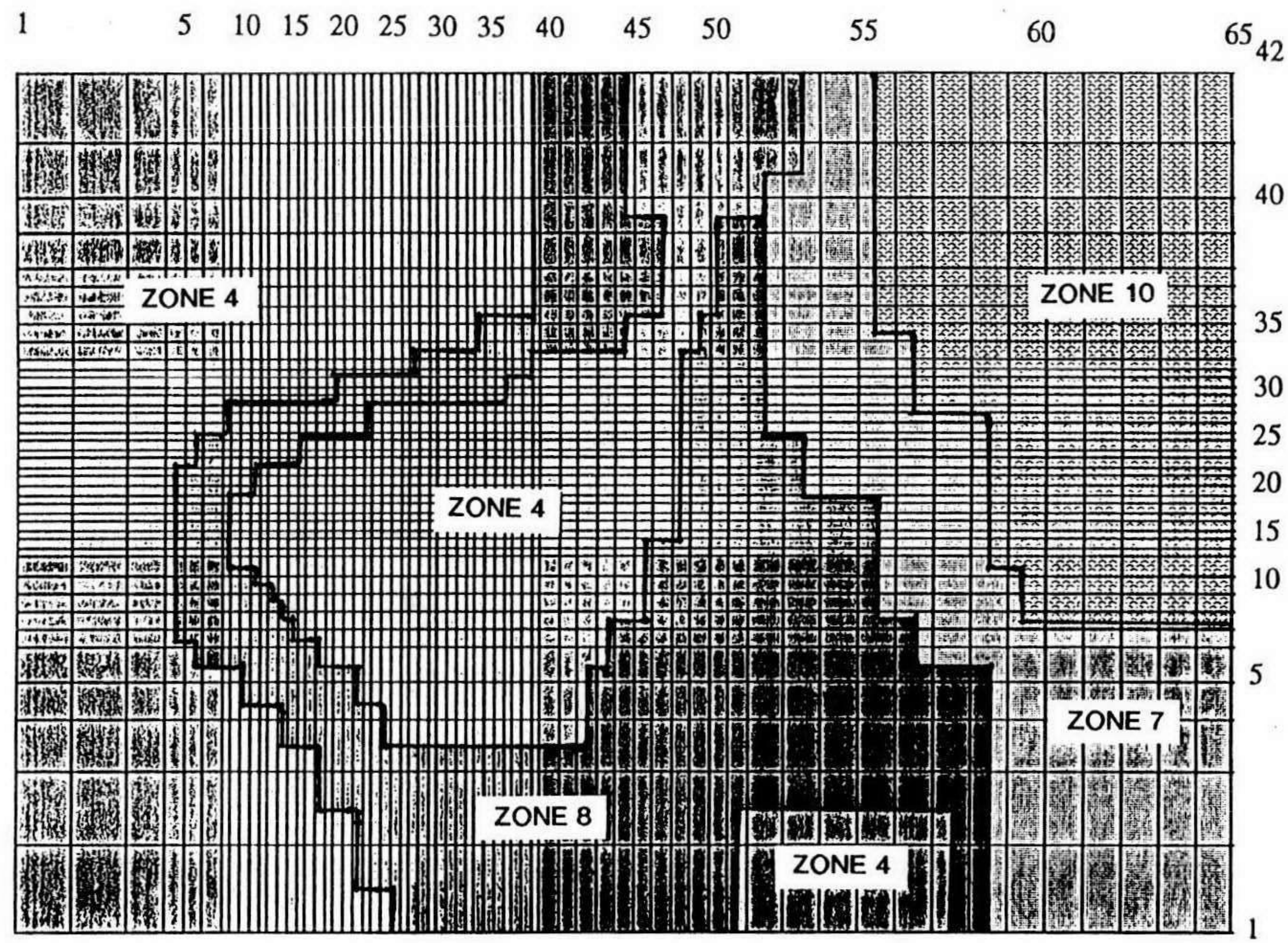
Horizontal Grid Definition.

Figure 6-15



Vertical Grid Definition.

Figure 6-16



Hydrofacies Zone Designation Layer 12.

Figure 6-17

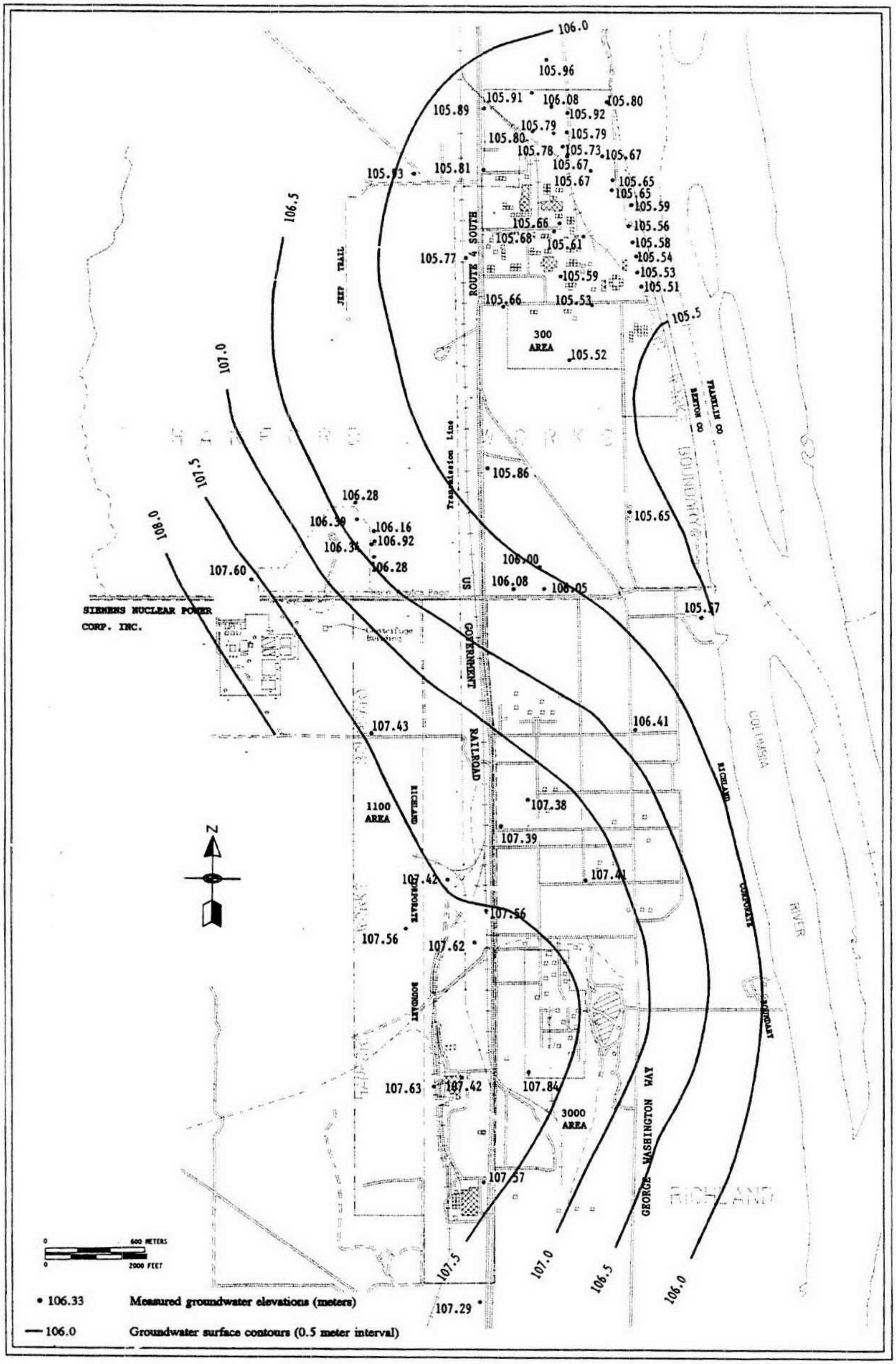
Table 6-11. 1100-EM-1 Groundwater Model Boundary Conditions

Location	Type	Range
Southwest Horizontal (Upgradient Boundary)	Constant Head Nodes	108.7 to 109.2[1](Upper)[2] 110.7(Lower Layers)
Southeast Horizontal	Constant Flux Nodes	0 to 0.45 meters/day
Northeast Horizontal (River)	Constant Head Nodes	105.3 to 105.65(High)[3] 104.35 to 104.7(Avg.) 103.65 to 104.0(Low)
Northwest Horizontal	Constant Flux and Constant Head Nodes (Columns 56- 65)	Flux = 0 C.H. same as River
Lower Vertical	Constant Flux	5.0E-4 meters/day (Upward)
Upper Vertical	Constant Flux	1.0E-5 meters/day (Downward)

[1] Elevations in meters

[2] Upper and Lower refer to the model layers representing strata above and below the silt aquitard

[3] High, Ave., and Low refer to the three representative river stages that were used for calibration.



Groundwater Levels and Potentiometric Surface Contours, June 25-27, 1990.

Figure 6-18

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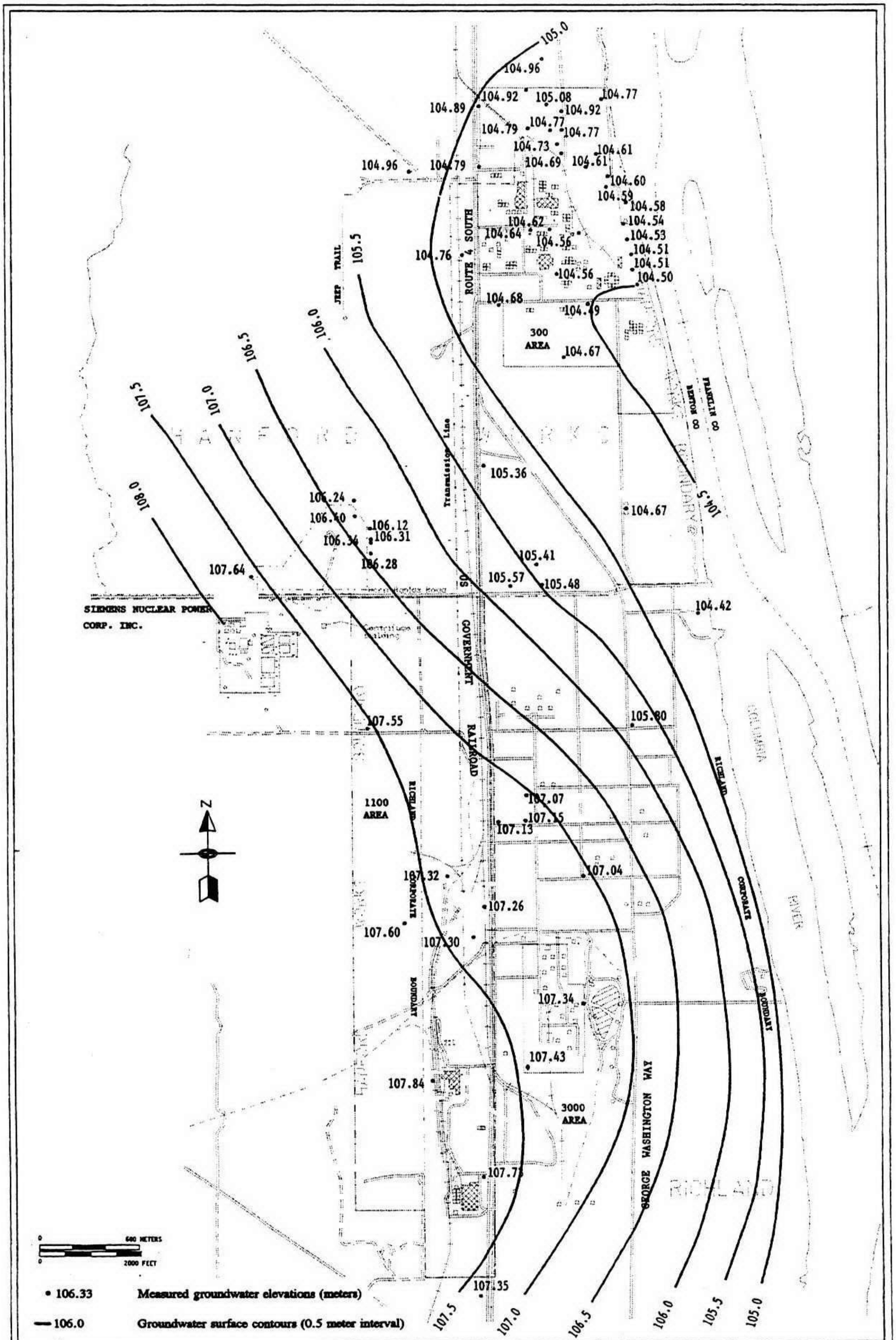
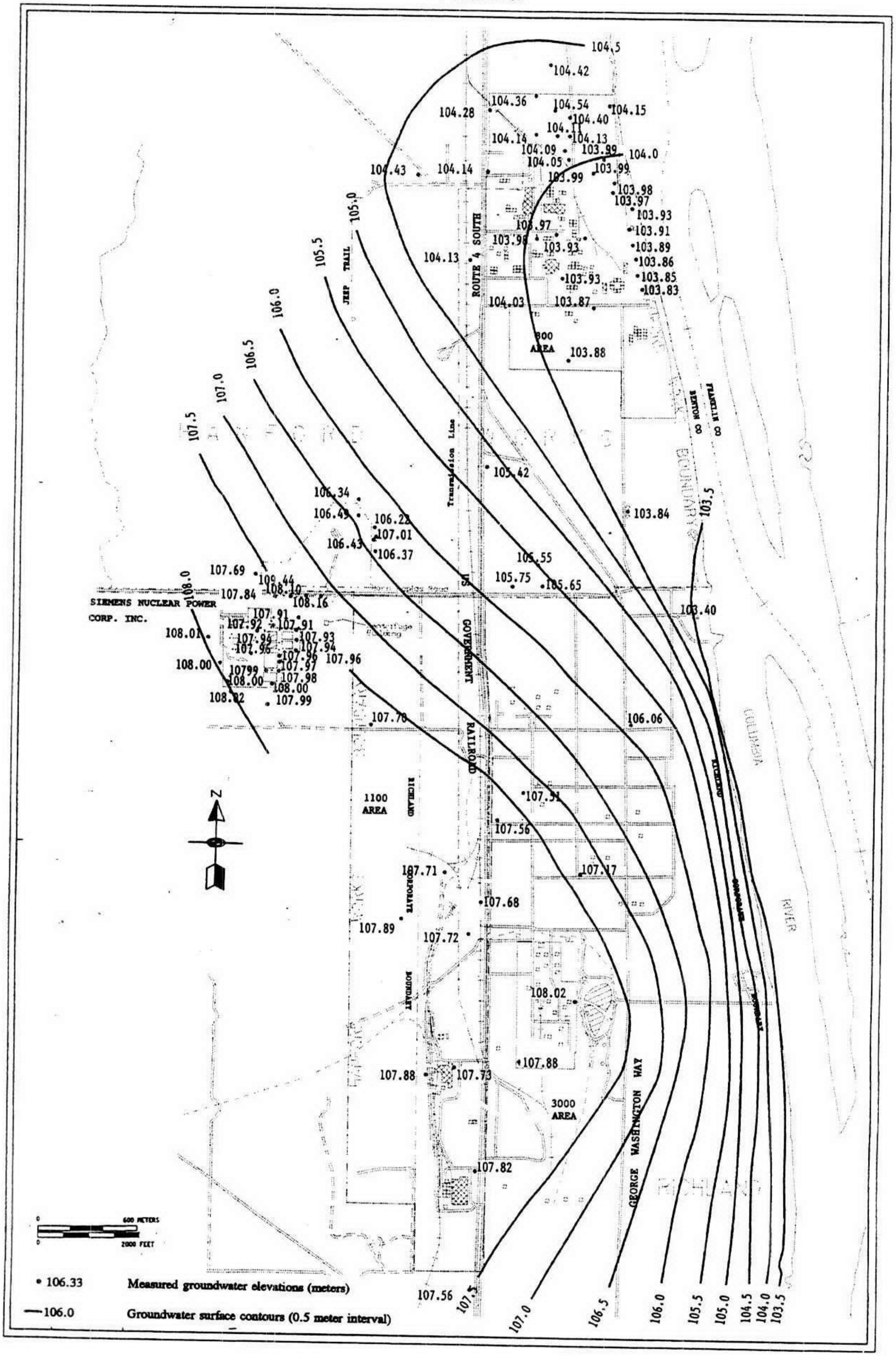


Groundwater Levels and Potentiometric Surface Contours, February 27-March 2, 1990.

Figure 6-19



Groundwater Levels and Potentiometric Surface Contours, September 24-27, 1990.

Figure 6-20

6.4.3.3 Computational Parameters. Hydraulic flow simulations were run in steady-state (*i.e.*, although the boundary conditions for each of the calibrations, representing the high, average, and low water table conditions, are different, only one set of conditions was used at a time). The number of time steps required, until a steady-state simulation converged, varied depending on the starting condition; several thousand steps required for a simulation starting from rough initial conditions to several hundred steps for restart files that have initial conditions close to the convergence conditions. Steady-state runs were typically initialized from restart files and used 1,000 time steps. Contaminant transport simulations were run in the transient mode in order to simulate plume migration through time. Time steps used in the transient mode ranged from 1 to 200 days depending on the time period being modeled. A typical transient run incorporated approximately 1,200 time steps.

Default matrix and governing differential equation solvers were used. The grid Peclet number remained below two during simulations. No significant mass balance errors were observed. See appendix H for input and output files, and for additional information on the computational aspects of the PORFLOW simulations.

6.4.3.4 Contaminant Transport. The contaminant transport portion of the model used the calibrated hydraulic flow parameters, then added source terms and contaminant transport parameters to simulate plume progression through time. Specific source term and contaminant transport data were not available for input to the model. Information on the TCE source was limited to a history of lagoon liner installation and repair at SPC (see source discussion in section 4). Quantities, timing, and location of the TCE source were determined, for use in the modeling analysis, by correlation with the lagoon liner history and matching plume progression with observed TCE groundwater concentrations. Because the exact source location is unknown, the simulated source area was not treated as a point source but as a volume 90 by 152 by 4 m (295 by 499 by 13 ft) located near SPC Lagoon No. 1. The best indicator of the contaminant transport parameters was the observed TCE plume and ranges of these parameters developed during the calibration process as discussed in paragraph 6.4.5.2. The observed nitrate data was not used for parameter estimation because the information did not allow for complete plume definition.

All simulations used retardation values directly, as discussed in paragraph 6.4.5.2, and were consistent with a linear adsorption-desorption assumption. This assumption is reasonable at low contaminant concentrations and is thus applicable at this site.

6.4.4 Sensitivity Analysis

Sensitivity analyses were performed on the flow and the contaminant transport portions of the model. The purpose of the sensitivity analyses was to determine the relative influence of the model input parameters on model results. The sensitivity analyses were performed prior to detailed model calibration.